

Sport Fishery and Wildlife Research 1974-75

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Fish and Wildlife Service

Divisions of Research

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

SPORT FISHERY AND WILDLIFE RESEARCH

1974-75

Activities in the Divisions of Research for the Fiscal Year 1974-75

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FOREWORD

A primary goal of the U.S. Fish and Wildlife Service is the conservation and sound management of sport fishery and wildlife resources for the benefit of present and future generations of Americans. Attainment of this goal requires the continual collection, analysis, and synthesis of new information on which wise and timely management decisions can be based. The Divisions of Research address the principal informational needs of the various management programs of the Service and provide many of the findings that contribute to the accomplishment of the Service's mission.

This summary of the activities of the Research Divisions during Fiscal Year 1975 provides an overview of the nature and scope of research completed, and directs attention to results that should be of significance in the management of fish and wildlife.

A substantial portion of the research recounted here concerns cooperative studies between Service scientists and those of other Federal agencies, universities, State agencies, and other countries. We thank the many collaborators for their most valued assistance in advancing the Service's diverse research program.

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A biologist inspects an osprey nest on Isla Ventana, Gulf of California. Management and preservation of fish and wildlife requires investigation of animal biology and the effects of the environment on animals, especially migratory birds, in many parts of North America. Fish-eating birds are often exposed to high levels of pesticides in their prey, and accumulations of pesticides in their bodies may reduce their reproductive success. (Photo by K. A. King)

SPORT FISHERY AND WILDLIFE RESEARCH

The research responsibilities of the Fish and Wildlife Service are carried out in four Divisions: Cooperative Research, Cultural Methods Research, Population Ecology Research, and Population Regulation Research. During fiscal year 1975, the Research Divisions continued to serve as the fact-finding arm of the Service. Facts about species of fish and wildlife, the environment required for their existence, and the effects of management practices on them help the U. S. Fish and Wildlife Service and other government agencies in their responsibilities for conserving and managing the Nation's fish and wildlife for social, economic, aesthetic, and scientific benefits. In fulfilling the Service's research responsibilities, the Divisions cooperate with agencies of the Departments of Interior, Agriculture, Defense, and Health, Education, and Welfare; the Atomic Energy Commission; the Agency for International Development, the Environmental Protection Agency; and various State agencies, institutions, and private organizations. Completed research is communicated by talks and lectures, processed reports, and articles in popular and technical publications. A list of publications is provided in this report.

During the fiscal year, research was carried out at 18

major facilities, approximately 60 satellite field stations, and 45 Cooperative Research Units under the following programs: Animal Damage Control, Environmental Contaminant Evaluation, Coastal and Anadromous Fish, Endangered Species, Great Lakes Fisheries, Inland Fishery Management, Environmental Impact Assessment, Migratory Birds, Mammals and Nonmigratory Birds, Reservoir Fisheries, Biological Services, and Cooperative Units. This alignment of programs permits the application of total agency resources toward the attainment of specifically detailed objectives and encourages careful priority assessment of ongoing research programs.

The planning, coordination, and administration of the research programs continue to be centralized in the Office of the Associate Director of Environment and Research in Washington, D.C. Fiscal, personnel, and property management and a variety of supporting services are provided the research facilities by the six Regional Offices of the Service. By the end of fiscal year 1975, the Divisions of Research had 377 professional employees and 398 non-professional employees. The budget included approximately \$20,200,000 of appropriated funds and \$1,973,000 of other funds.

ANIMAL DAMAGE CONTROL

Denver Wildlife Research Center

Hazards of pocket gopher control to other wildlife.—A cooperative study with the Environmental Protection Agency was begun to evaluate the primary and secondary hazards inflicted on nontarget wildlife by pocket gopher control. The study was conducted on the Sherburne National Wildlife Refuge in central Minnesota, an area consisting of deciduous forest, wetland, and old field habitats. A 9-square-mile area was treated for pocket gopher control, and a larger area served as an untreated reference. Within the treated area, approximately 1,500 acres (75% of the old fields) were baited with 0.5% strichnine-treated milo at 1.5 pounds per acre applied underground with the burrow-builder in a manner simulating large-scale control on agricultural lands. Pocket gopher activity was reduced 85-90% following the baiting.

Primary hazards to seed-eating birds were measured by marking 200 territorial male red-winged blackbirds with numbered streamers. The presence of these birds on their

territories after treatment was used as an index to hazards to other seed-eating birds in the area. Primary hazards to small rodents, such as harvest mice, meadow mice, jumping mice, and ground squirrels, was assessed by trapping (4,000 trap-nights), marking, and releasing the rodents before and after baiting on the treated and reference areas. Secondary hazards to predatory birds and mammals were determined by placing radio transmitters on 36 raptors (red-tailed hawks, kestrels, and great-horned owls) and 36 mammals (badgers, foxes, skunks, and coyotes) and monitoring their daily movements before, during, and after treatment. Carcass searches and counts of nestling birds provided supplemental information.

Although the data have not been analyzed, it appears that underground baiting to control pocket gophers results in only minimal hazards to predatory mammals, birds of prey, and seed-eating birds. There does, however, appear to be a measurable reduction in small rodents, particularly mice, as shown by a slight decrease in posttreatment trap success on the treated area.



Pocket gophers damage crops and range forage by raising earth mounds (left) and feeding on plants. Control methods for pocket gophers must not harm other animals such as the badger (right), which is a major



predator of the gopher in central Minnesota. The badger wears a miniature radio transmitter to trace its movements and the effect of gopher control on it. (Photos by Paul Springer, left; Denver Research Center, right)

Secondary hazards of rodenticides to kit foxes.—Grains treated with 1080, strichnine alkaloid, or zinc phosphide are commonly used to control ground squirrels within the range of the San Joaquin kit fox in California. The secondary hazards of 1080 to kit foxes and other species have been recognized for many years, but little definitive information is available for strichnine and zinc phosphide. To appraise the potential of these rodenticides for hazards under field conditions, a series of laboratory tests was conducted with the three compounds. The desert kit fox was tested in lieu of the San Joaquin kit fox because the latter is an endangered species. Preliminary tests to determine toxicity showed acute oral LD₅₀'s (doses that kill 50% of the animals treated) of 0.22 mg/kg for 1080, 0.75 mg/kg for strichnine alkaloid, and 93.0 mg/kg for zinc phosphide.

To determine secondary hazards, kangaroo rats were gavaged (fed by stomach tube) with multiples of the kit fox LD₅₀ and fed to foxes shortly after death. One fox, fed a single kangaroo rat dosed with 1080 at a level equivalent to two kit fox LD₅₀'s, died within 12 hours. Another fed a kangaroo rat dosed with strichnine alkaloid at a level equivalent to 10 kit fox LD₅₀'s died within 30 minutes. Each of two foxes was offered a kangaroo rat treated with the equivalent of three fox LD₅₀'s of zinc phosphide. Both foxes ate the rats whole, regurgitated them within 1 hour, then reconsumed them overnight with no further reaction. Additional rats, treated at the same level, were offered the 2nd and 3rd days with similar results. Each of these two foxes consumed approximately 3 LD₅₀'s per day for 3 consecutive days with no lasting

effects. A third fox, offered zinc phosphide-treated kangaroo rats for 3 days, refused to eat the first 2 days, then ate one rat, regurgitated, and reconsumed the rat without further reaction.

This study indicates that kit foxes probably will eat freshly poisoned kangaroo rats under field conditions. From the standpoint of primary and secondary hazards, zinc phosphide is safer than either 1080 or strichnine alkaloid. Its relatively low toxicity, emetic properties, and effectiveness as a rodenticide make it a logical choice for



The secondary effects of certain toxicants were studied on the desert kit fox, used in experimental studies as a substitute for the San Joaquin kit fox, a threatened species. The toxicants are used to control ground squirrels in the range of San Joaquin species. (Photo by Judith Johnson)

controlling field rodents within the range of the San Joaquin kit fox.

Black-tailed prairie dogs increase in South Dakota.—Black-tailed prairie dogs have received minimum control on Buffalo Gap National Grasslands in South Dakota since 1969. Aerial photographs of 400 square miles of this area taken in June 1968 showed 114 prairie dog colonies, which were mapped and measured. Colony size ranged from less than 1 acre to 422 acres, and the area occupied by prairie dogs totaled 3,079 acres. Aerial photographs of the same area, taken in May 1974, showed a dramatic increase during the 6-year period in both the number of colonies and the area occupied by prairie dogs. The number of colonies increased 61%, from 114 to 184. Almost 50% of the colonies observed in 1974 had not been present in 1968, indicating a high degree of pioneering to establish new colonies. These new colonies were small, however, and did not contribute much to the increase in colony acreage. The total acreage occupied by prairie dogs more than tripled, from 3,079 acres in 1968 to 9,764 acres in 1974. Peripheral expansion of colonies



Porcupines cause thousands of dollars worth of damage annually to wood structures and signs. A cooperative study with the U.S. Forest Service determined which of 27 products tested were least susceptible to damage. (Photo by James Evans)



Knowledge of the biology and ecology of the black-tailed prairie dog is essential to develop management techniques. The pups are flushed from their burrows for measurements and study. (Photo by Keith LaVoie)

present in 1968 accounted for 91% of this increase. The most dramatic expansion was observed in larger colonies. In 1968 the largest colony occupied 422 acres; it had expanded to almost 2½ square miles (1,600 acres) by 1974.

These studies indicate that, under programs of minimum control, prairie dogs can expand their numbers at an alarming rate. In this instance, serious conflicts were created with acceptable management of the National Grasslands.

Sign materials avoided by porcupines.—The U.S. Forest Service estimates that 10% or more of their plywood signs on National Forests are irreparably damaged by porcupines each year in several northern and southwestern States; the annual loss in Montana alone is estimated at \$10,000. In a 4-year cooperative study with the U.S. Forest Service, 27 materials used in constructing signs were tested for their relative susceptibility to damage by porcupines in critical damage areas in Colorado, Idaho, Michigan, Montana, Oregon, and Vermont. Those most consistently avoided by porcupines were retested each winter. Finally, three materials—pressed board, ABS plastic (a commercial product used for roadway

signs), and plywood fabricated with a special melamine/urea adhesive—proved to be 92-94% less attractive than standard plywood signs to porcupines. Signs made of the melamine/urea adhesive-bonded plywood are now available for use in porcupine problem areas.

Reproductive inhibitors for white-tailed deer.—From 1968 to 1975 a series of studies on deer reproduction was conducted at a field research station in Mammoth Cave National Park, Ky., in cooperation with the National Park Service. Reproductive inhibitors were evaluated as a means of regulating populations of deer in areas where hunting is either prohibited or not feasible. Reproductive physiology, physical condition, productivity, and other population characteristics of the free-ranging white-tailed deer herd in the park were studied as a basis for applying and evaluating the effects of reproductive inhibitors on the herd. It was anticipated that these studies might lead to development of methods adaptable to other problem areas and species.

Experiments with oral reproductive inhibitors for captive deer centered on two compounds—melengestrol acetate (MGA), which interferes with ovulation, and diethylstilbestrol (DES), which causes abortion. MGA fed to does in daily doses of 0.6-1.0 mg during the breeding season was effective in preventing pregnancy. However, this same dose range fed every 3rd day during the breeding season (a regimen more consistent with field application) resulted in 50% conception, which was considered inadequate. High doses of 1,000 mg MGA, fed either in a single dose prior to the breeding season or every 30 days during the breeding season, failed to prevent pregnancy. A microencapsulated formulation of DES fed at 1,000 mg every 17 days throughout the breeding season also failed to prevent pregnancy because of poor bait acceptance. Two different types of mechanical antifertility devices, designed to prevent copulation or create an unfavorable environment for sperm, likewise failed.

More promising results were obtained when tube-type and solid silastic implants containing a progesterone compound were implanted beneath the skin of does. These were effective in preventing pregnancy for two breeding seasons (tube-type) or three seasons (solid silastic).

These studies indicate that, with current technology, the regulation of deer populations with chemosterilants may be restricted to the use of implants. However, implants may have limited application because of their relatively short effective period and the necessity to capture animals for treatment. Treating herds by baiting does not appear feasible with the chemosterilants currently available.

Sheep losses recorded for Idaho shed-lambing operations.—Sheep mortality data have been tabulated for 2 years from three Idaho ranches that lamb in sheds.

Loss assessments were derived from checking sheds during the 2.5-month lambing period and by monitoring sheep bands by horseback during the 9.5-month range period. Mortality among lambs was 11.3% (1,455 of 12,836) in 1973 and 15.2% (2,104 of 13,808) in 1974. Lamb losses on the range were 5.2% (623) in 1973 and 5.7% (713) in 1974. Minimum confirmed predation on lambs was 1.1% (141) in 1973 and 1.7% (208) in 1974, and maximum possible predation (including unaccounted-for losses) was 4.4% and 4.6%. Losses of ewes totaled 6.8% (595 of 8,750) in 1973 and 5.8% (528 of 9,073) in 1974. Ewe losses on the range were 5.9% (509) in 1973 and 4.2% (374) in 1974. Confirmed predation on ewes was 1.4% and 0.7%, respectively. Most lamb losses, both verified and unaccounted-for, occurred between range turnout (1 April) and entrance onto forest lands (1 June). Coyotes were responsible for 95% of the verified predation losses.

These minimum figures for confirmed predation are in the range of those found in some other damage assessment studies; the maximum possible predation figures exceed the upper limits of most recently completed studies. Predation on sheep varies considerably among ranches, but the economic impact may be significant to an individual rancher whether 5 or 50 lambs are killed.

Guidelines for field use of toxic collars.—Enclosure tests at Logan, Utah, and field studies in Texas and Idaho were undertaken to determine the best means of presenting lambs fitted with toxic collars in areas where coyotes are killing sheep. Tethering collared lambs is safer than using free-roaming animals, but the response of coyotes to tethered prey has not been documented. At the Logan enclosure, where coyotes were offered a choice between a tethered and a free lamb, they chose the tethered lamb in four of five trials. The results of the field tests in Texas were interesting; the wild coyotes there were not sheep killers, and they repeatedly ignored both free and tethered lambs. The use of an attractant on the lambs and baiting with fresh meat still did not result in lamb kills. Tests in Idaho, where lambs were tethered in or near sheep flocks under attack, indicated more promising results. Coyote predation rates were 7.80 kills per 100 exposure nights for tethered lambs and 0.5 kills per 100 exposure nights for lambs in the flock. Thus, a tethered lamb was 150 times more likely to be killed than one in the flock.

The pen and field trials conducted thus far suggest that the toxic collar technique should be employed only for coyotes that are actively killing sheep, that the method may be expensive but useful where conventional methods are not successful, and that the placement of collared lambs relative to kill sites and coyote travelways is critical.

Electric fencing investigated to control coyote pre-



The extent of coyote predation on sheep is controversial and studies on the range have been necessary. Sheep losses to predators have been less in high country than at lower elevations. (Photo by Roger Nass)

dation.—The results of a preliminary pen test suggest that electric fencing may be feasible as another nonlethal control method to reduce livestock loses to predators. Four adult coyotes, two males and two females, were tested in individual 12- \times 6- \times 6-foot solid-walled pens. Three strands of 18-gauge, smooth electric fence wire, connected to a fence charger and spaced at heights of 8, 16, and 24 inches, were placed 4 feet in from the front of the pen so that the coyote would have to cross the barrier to reach a tethered live rabbit. Phases 1, 2, 3, and 5 of the study each consisted of 10 consecutive days with 20-hour daily test sessions; phase 4 was 3 consecutive days with 4-hour daily test sessions.

In phase 1, the coyotes' daily ration of dry dog food was reduced by one-fourth, and the electric barrier was charged. Three of the four coyotes would not cross the barrier to kill the prey, but the fourth, a male, consistently went under the barrier with no visual reaction to the charged wires. He was dropped from the test, since he did not meet the criterion for further testing. Phase 2 was identical to phase 1 except that the three wires were not charged. The three remaining test coyotes still would not cross the barrier. In phase 3, the coyotes were deprived of their daily dog food ration, and the only source of food was the rabbit on the other side of the barrier. In this phase, the barrier was charged. During 10 consecutive test

periods, or 200 test hours, the three coyotes would not cross the barrier. In phase 4, the coyotes were again put on their three-fourths daily ration of dry dog food and the barrier wires were removed. For a few minutes during the 1st day, the coyotes paced back and forth where the electric wires had formerly been located. After a short time, they crossed this imaginary barrier and killed the prey. During the following 2 days, they killed without hesitation. In the final (5th) phase, the electric fence wires were replaced at their former heights and left uncharged. The coyotes continued to receive a three-fourths daily ration of dry dog food. None of them crossed the barrier.

In summary, three of four coyotes completed the four phases, or a total of 800 hours, during which they did not kill the prey presented to them on the other side of the electric barrier, whether it was charged or not. However, when the barrier was removed (for a total of 12 hours), they killed the prey almost immediately.

Canine teeth are best for aging coyotes.—In carnivores, the canine tooth is the one most often extracted and examined after decalcification, sectioning, and staining to determine age by counts of the annuli in the cementum. The canine tooth of the coyote, however, has a large, deep root, making it difficult to extract. Aging by tooth extraction may be useful in studies in which coyotes are captured, marked, and released. To determine whether a

tooth more easily extractable than the canine would provide equally reliable estimates of age, annuli counts of four kinds of teeth were compared. A canine, third incisor, second premolar, and first premolar (when available—five were missing) were taken from jaws of 13 adult coyotes collected in Atascosa County, Texas. The prepared sections of the teeth were examined under a compound microscope at 40 \times and 100 \times .

There was a noticeable difference in the number of annuli found in different teeth from the same animal. Annuli in the premolars and incisors often merged together, and many were poorly defined. The canine sections were always easier to read and usually had the best defined annuli. In the sample of 13 coyotes, annuli counts averaged 3.0 in canine teeth, 2.0 in third incisors, and 2.4 in second premolars. Although the canine is more difficult to extract than the other teeth, these findings indicate that it is the most reliable tooth for age determination, and that

the use of incisors or premolars may result in underestimates of age.

A very successful coyote workshop.—A Coyote Research Workshop, sponsored by the Denver Wildlife Research Center, was held at a Denver hotel 14-17 November. The purpose was an exchange of scientific information among the many Federal, State, and university workers concerned with predator research. The sessions covered four grueling, information-packed days, with a full day of papers devoted to ecology, behavior, damage assessment, and depredations control. Nearly 250 people attended, including many visitors from various conservation groups and the sheep industry. The exchange of information and attendance at sessions were outstanding, and the workshop was believed to greatly advance the progress of predator research. Abstracts of the 65 papers presented were published in the Denver Center's "Coyote Research Newsletter."



The physical development of coyote pups and the social structure of the litters are being studied at the new observation area and pen complex, Millville Research Site, Logan, Utah. (Photos by Richard Burns)

Aversive drugs tested for conditioning coyotes.—Restrictions on the use of toxicants have increased research efforts to develop nonlethal methods of protecting sheep from coyotes. One method that has been proposed is drug-induced aversive conditioning. According to this concept, coyotes can be made to associate the unpleasant effects of an aversive drug with a certain kind of prey, so that they will avoid attacking that kind of prey in the future.

Successful use of this method depends on finding a safe and effective aversive drug and on developing a system for delivering it to coyotes in the field. Thus far, four drugs have been evaluated with 15 coyotes that had learned to kill deer mice and white rabbits placed in their pens. After each coyote had killed and fed on one rabbit, for example, a second rabbit was presented 24 hours later. Within 5-10 minutes after it killed this rabbit, the coyote was restrained and orally dosed with cantharidin, digitoxin, nicotine sulfate, reserpine, or cornstarch (control). Its predatory behavior toward rabbits and deer mice was then observed and timed in subsequent sessions. Two of the drugs, cantharidin and nicotine sulfate, proved unacceptable as aversive agents because several coyotes died after treatment. Up to three doses of reserpine and cornstarch produced no change in attack and kill behavior toward the prey. Only digitoxin delayed or suppressed killing of prey; if used at higher dose levels, this drug may hold some promise as a candidate aversive agent for field use.

Rat control by sustained baiting.—Fish and Wildlife Service biologists based at the Rodent Research Center in the Philippines are currently evaluating a variety of control methods there and in other Southeast Asian countries. Previous trials indicated that the use of chronic toxicants, such as anticoagulants, in ricefields from transplant to harvest could effectively and economically reduce damage by ricefield rats (*Rattus r. mindanensis*) a common pest in major rice-growing regions of the Philippines. During 1974, sustained baiting was tested in a 135-ha ricefield area where another ricefield rat (*R. argentiventer*), was a major pest and rat damage had limited production in the past. A 106-ha ricefield with negligible rat control but similar to the treated area in habitat, rat populations, and rice harvests was used as a reference area. In this trial, rat activity in the treated area was significantly lower than in the reference area for the entire length of the growing season. Damage appraisals of the harvested crop indicated that 27.6% of the hills in the reference area were damaged, but only 4.0% in the treated area. Farmers in the treated area harvested about 2,115 kg/ha of rice, almost twice the average harvest in the reference area, which was 1,165 kg/ha. Rat control in the treated area cost less than \$3/ha, and its farmers made a net profit of \$238/ha. This was over twice the profit of

farmers in the reference area (\$106/ha).

A second trial with sustained baiting was conducted on Luzon in a 12-ha ricefield farm adjacent to marshes where *R. r. mindanensis* had limited production for two growing seasons. At harvest, about 5.6% of the tillers (grain-bearing stems) in the treated area had been cut by rats, and the farmer was able to harvest 4,200 kg/ha of rice, over twice his two previous harvests. His net profit was over \$400/ha, with about \$4/ha invested for the sustained-baiting program. A similar reference area received negligible rat control. Over 90% of the tillers were cut by rats in this area; 125 kg/ha of rice were harvested, and the farmer lost about \$93/ha on his crop.

Zinc phosphide for rat control in Hawaiian sugarcane.—A zinc phosphide-treated oat groat bait was registered in 1970 to control rat damage in Hawaiian sugarcane through cooperative efforts with the Hawaiian Sugar Planters' Association and the Hawaii State Department of Agriculture. Under experimental conditions, the original bait formulation reduced damage at harvest by approximately 49%. Formulation amendments to the registration increased efficacy and reduced damage by approximately 60%.

The bait's efficacy in an actual control operation has been assessed by examination of rat loss records for one



Bait stations developed by Denver Wildlife Research Center biologists work well with anticoagulant baits. They can be constructed by farmers at negligible cost from locally available materials. (Photo by Russell Reidinger)

large plantation beginning with the 1971 crop year. This area has traditionally suffered considerable rat damage, and about 62% of the 8,918-acre plantation has been routinely baited. Each year, 4,000 to 6,000 acres were sampled for damage; estimates of tons of sugar per acre lost to rats were calculated from the percentage of rat-damaged stalks that were dead or soured at harvest.

On the plantation, rat-damaged stalks at harvest have dropped from an average of 26% in 1967-70 (before zinc phosphide was used) to 16.7% in 1971-72 and 12.4% in 1973-74. The estimated mean annual sugar loss to rats during the first 4 years of baiting with zinc phosphide was 1,632 tons, versus 3,128 tons during the preceding 4 years. This difference represents a mean annual financial gain (based on 1974 average value of \$670 per ton) of over \$1 million for this plantation alone. These figures include losses from untreated areas. If the 1971-74 reduction in damage was due primarily to zinc phosphide treatment, the baiting program reduced sugar losses in treated areas by approximately 75%.

For the plantation as a whole, the 1974 mean loss to rats was 0.79 ton of sugar per acre in unbaited areas, 0.35 ton per acre in baited fields. The difference (0.44 ton per acre) represents a gain of \$295 per acre. Balanced against total treatment costs of \$7 per acre, the 1974 cost-benefit ratio was 1:42.

Anticoagulant effective against warfarin-resistant rats.—Service biologists are cooperating with the World Health Organization (WHO) by evaluating candidate rodenticides that are in the advance stages of development. Each rodenticide submitted by WHO is accompanied by efficacy and toxicological data that indicate what value it may have in Fish and Wildlife Service programs. One of these rodenticides, the anticoagulant Difenacoum, gave excellent results in feeding tests with strains of Norway, ricefield, and Polynesian rats that were not resistant to anticoagulants. Since the manufacturer claims that Difenacoum is also effective in warfarin-resistant rats, arrangements were made to obtain warfarin-resistant wild Norway rats from the New York State Rodent Control Bureau. These rats had previously survived feeding tests in which they consumed 15-28 mg/kg of warfarin (mg/kg of body weight).

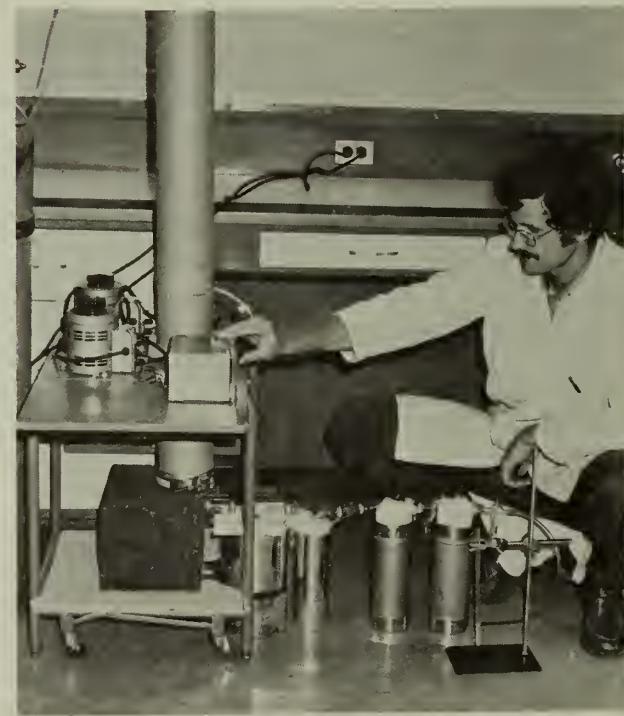
Difenacoum was incorporated into an oatmeal bait at 0.005% and offered as the only source of food for 6 consecutive nights to eight nonresistant and eight resistant wild Norway rats (four males and four females each). All 16 rats died within 5 to 8 days after exposure to the treated bait. The nonresistant rats consumed 6.5-14.3 mg/kg of Difenacoum, and the resistant rats consumed 7.1-14.0 mg/kg.

Difenacoum is manufactured by a British firm and has not been registered for use in the United States.

Oils and rice-flavor volatiles as bait additives.—Rice-field rats (*Rattus r. mindanensis* and *R. argentiventer*) cause considerable losses of rice and other food crops in the Philippines and throughout Asia. To date, baiting has been the most commonly used method for controlling damage by these species, but bait acceptance is often a problem. A bioassay has been developed to evaluate odor and flavor additives for baits that could attract rats to bait stations, increase their consumption of toxic baits, and possibly mask the symptoms associated with sublethal doses of toxicants.

Tests with 15 commercial flavoring agents (sweeteners, proteins, and cereal flavor enhancers) showed no effect on ricefield rats' taste preference at any concentration. However, adding a 10% concentration of corn, soy, peanut, linseed, or rice oil to rice bait markedly increased consumption. Often, untreated rice was almost completely ignored when oil-treated rice was available. Rice oil was particularly effective, and all rats that were tested preferred rice treated with rice oil to untreated rice. Palm oil and coconut oil, which are readily available and inexpensive in the Philippines, are now being tested.

Another approach to increasing the attractiveness of rice baits was the addition of a concentrate of the volatiles that contribute to the flavor of unprocessed rice. These



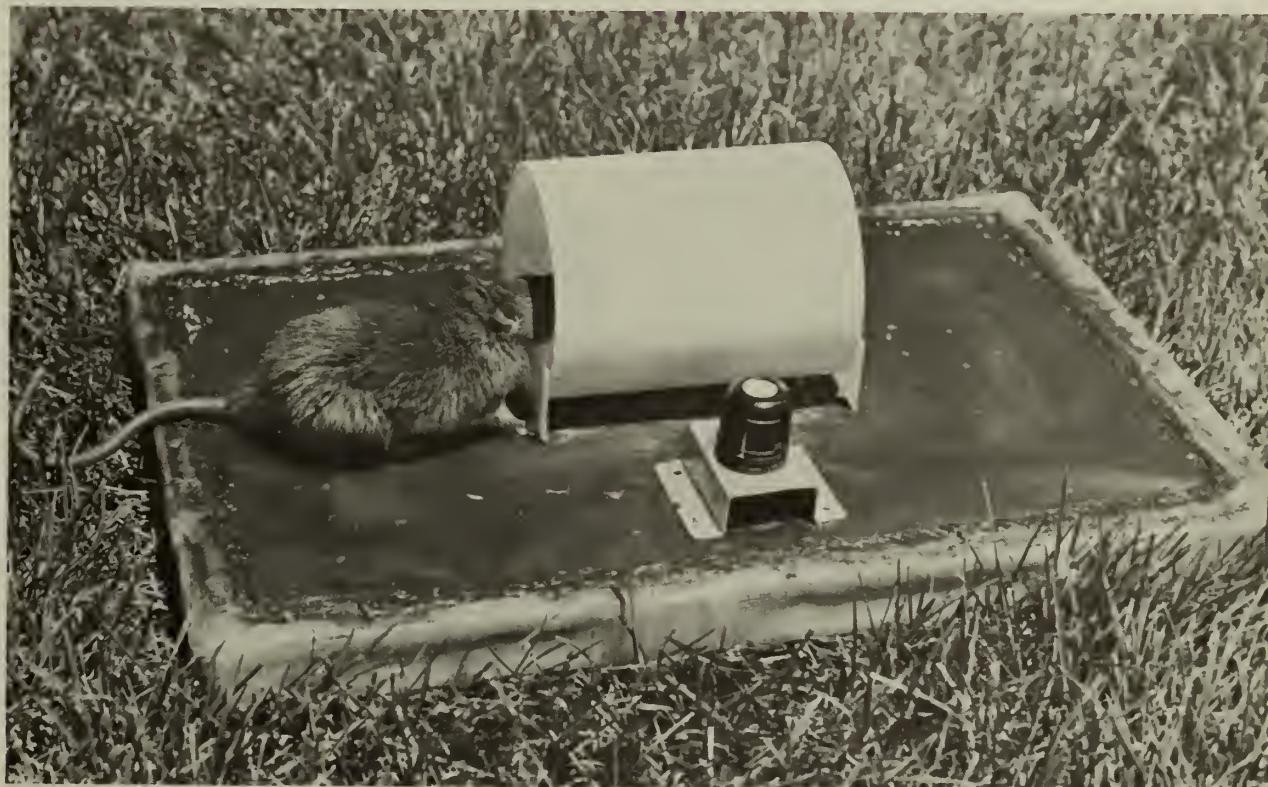
An apparatus used for the collection of rice volatiles. The "rice aroma" fraction collected in the apparatus is an excellent bait enhancer for Philippine ricefield rats. (Photo by Stanley Gaddis)

have consistently been very effective in increasing rats' consumption of rice bait in laboratory tests. Because a synthetic rice-flavor concentrate could be a potent, easily handled bait enhancer, a method was developed to collect the volatile fraction from ground wholegrain rice so that its components could be chemically identified. Altogether, 73 compounds, all but a few of the major components of the volatile fraction, were identified by combined gas chromatography-mass spectrometry, and the identity of 31 more was predicted. Of the compounds identified, 63 had not been previously reported in rice, and 54 of these, not in any cereal grain. The next step will be to determine if these additives will increase the attractiveness and consumption of toxicant-treated baits.

Coulometric recorder designed for timing and counting events in the field.—A unique event recorder has been developed to monitor the feeding activity of ricefield rats in the Philippines. The recorder uses coulometers (components that record each passage of an electrical charge by a proportional chemical change) for data storage, and a simple treadle switch on a feeding monitor allows them to record the accumulated feeding time and number of visits to a food source. Unlike conventional electromechanical timers and counters, the coulometric recorder is silent,

relatively inexpensive and operationally simple, and requires only microwatts of battery power. The stored data are recovered with less than 6% error by a simple laboratory instrument, and the coulometers can be reused indefinitely. The advantages of the new recorder for field situations are already suggesting a variety of other research applications.

Effect of vampire bat parasitism on milk production of dairy cows.—The contention that vampire bat parasitism, even in the absence of disease, is debilitating and will result in lower milk production of dairy cattle was investigated under field conditions. Milk production and several hematological indicators were measured before and after controlling moderately severe vampire parasitism on 58 lactating Holstein cows near Quito, Ecuador. Systemic treatment of the cows with single intraruminal injections of 1 mg/kg of an anticoagulant, diphenadione, reduced vampire attacks by 98% from a pretreatment mean of 4.0 bites per cow to 0.1 bite per cow posttreatment. At 30 days posttreatment, red blood cell counts, packed cell volumes, and milk butterfat content showed small but significant increases ($P < 0.05$). However, milk production remained virtually unchanged from a pretreatment mean of 28 pounds per cow per day. Apparently, where disease



Ricefield rat feeding at an activity monitor. These monitors, designed for use in the Philippines, record the accumulated feeding time and number of visits to a food station and store the data in a coulometer. (Photo by A. Lawrence Koltz)

is not a factor and cattle are healthy, blood loss from moderately severe bat parasitism has no effect on milk production.

Cowbirds from the Northern Great Plains winter in Mexico.—During the past 40 years, more than 2,000 brown-headed cowbirds have been banded at Sand Lake National Wildlife Refuge in South Dakota from May to September. The 20 birds that have been recovered to date indicate that this population breeds in the Northern Great Plains from South Dakota to Saskatchewan and winters in west-central Mexico. Eight of the 20 recoveries were from the Mexican states of Guanajuato, Michoacan, and Jalisco. The recovery rate for normally banded cowbirds was 0.4% and the rate for cowbirds marked with colored plastic leg-streamers was 1.4%.

Methiocarb reduces bird damage to wheat and rice in Africa.—During January and February 1974, a biologist, in cooperation with local personnel, conducted field experiments on methods of reducing damage by quelea (red-billed weavers, *Quelea quelea*) to ripening wheat near Nanyuki, Kenya, and to ripening rice near Rujewa, Tanzania. The experimental bird repellent, methiocarb, was effective in reducing quelea damage to both crops. In both tests, small plots were sprayed with a formulation of 3 pounds (active) methiocarb in 15 gallons of water. In the wheat test, a 0.25-acre plot was selected for treatment and a similar 0.25-acre plot as the control; both plots were located at the edge of large fields and both were bordered by brush and grass tracts. In the rice test, a 0.12-acre plot was treated and a similar 0.12-acre plot was the control.

Posttreatment damage surveys in wheat indicated 8 times more damage on the control plot (493 plants damaged per 1,000) than on the treated plot (60 per 1,000). In rice, the damage was 10 times greater on the control (510 per 1,000) than on the treated (50 per 1,000) plot. In and around the wheat plots, 2 times more birds were estimated per observation on the treated plot (1,278 birds) than on the control plot (612) before treatment, 3 times more birds on the control (629) than on the treated (182) after treatment. In rice, there were 2 times more birds per observation on the control plot (65) than on the treated (32) before treatment, 5 times more birds on the control (174) than on the treated (39) after treatment.

Philippine weaver birds can cause severe rice damage.—As part of a continuing program to survey agricultural damage by mammals and birds in Southeast Asia, cage studies were conducted with three species of Philippine weaver birds, *Lonchura punctulata*, *L. malacca*, and *L. leucogaster*, which are known as grain pests in Asian ricefield areas. Feeding tests with growing plants indicated that an individual of these species has the potential of removing or destroying 7-10 g of rice grain a day. Although all three species damaged both green and



Spraying wheat with methiocarb to control damage by the quelea, or red-billed weaver. In Africa, biologists of the Denver Wildlife Research Center's AID (Agency for International Development) program are studying methods for controlling bird damage to crops. (Denver Center photo)

maturing rice, significant differences were noted in their feeding patterns, which may allow identification of damage by species in field appraisals.

In preliminary tests to evaluate approaches to reducing damage by the weaver bird species, the acute oral toxicities of two chemicals, fenthion and methiocarb, were determined, and birds were caged in ricefield plots treated with 0.05-0.20% of these chemicals. Results of these studies indicate that the three species are more sensitive to fenthion than to methiocarb, and that *L. leucogaster* is the least sensitive to either compound.

Chemical frightening agent not translocated into crop plants.—An application to register the chemical frightening agent, 4-aminopyridine (4AP), for protecting ripening sunflowers from blackbird damage has been submitted to the Environmental Protection Agency. In field use, cracked corn baits treated with 4AP and diluted 1:99 with untreated cracked corn are broadcast in fields being damaged. Blackbirds that ingest treated particles give distress reactions that frighten away the rest of the flock. Although the application rate of 4AP is only 1 pound per 3,333 acres, its intended use on food or feed crops dictated that the potential for translocation of 4AP from the soil into sunflowers and rotational crops, such as wheat, be determined. Sunflower plants (both oil and confectionery varieties) and wheat plants were grown in a greenhouse for 8 weeks in soils collected from North Dakota sunflower fields and treated with 20 ppb (parts per billion) of ¹⁴C-labeled 4AP (approximating the accumulation from 20 baitings during a damage control program). The plants contained no radioactivity due to the labeled 4AP when

harvested 1, 2, 4, and 8 weeks posttreatment.

Avitrol reduces blackbird damage to ripening sweet corn.—Data collected during August 1974 in Wisconsin and Idaho showed that aerial application of a commercial 4AP-cracked corn bait (Avitrol FC Corn Chops-99) at the rate of 1 pound per acre was effective in reducing blackbird damage to ripening sweet corn without apparent hazard to nontarget bird species. On 15 randomly selected 40-acre plots per field, blackbirds damaged 10 times as many kernels and 6 times as many ears in untreated as in treated fields in Wisconsin, and 4 times as many kernels and 3 times as many ears in untreated as in treated fields in Idaho. Red-winged blackbirds were responsible for most of the damage.

No nontarget birds were found dead during a search of 5% of the treated acres (7.3 acres in Wisconsin and 8.2 acres in Idaho); 22 dead blackbirds (12 in Idaho and 10 in Wisconsin) were found during these searches.

In New York, Ohio, and Maryland, Avitrol was less effective in controlling blackbird damage to sweet corn (as related in the following section).

Patuxent Wildlife Research Center

Efficacy of Avitrol in protecting sweet corn from blackbird damage.—The efficacy of the bird frightening chemical, Avitrol, was tested in New York, Ohio, and Maryland in 1974. Aerial application in each test was made at an average rate of 1 pound per acre per application. Treated fields were selected at random and compared with untreated fields.



Ear of sweet corn damaged by blackbirds. Biologists of the Denver and Patuxent Wildlife Research Centers are conducting investigations to control damage to sweet corn and other crops by blackbirds. (Photo by Charles Stone)



Test of chemical translocation in plants. Detectable amounts of 4-aminopyridine labeled with a radioactive chemical were not translocated in sunflowers and rotational crops, such as wheat, in laboratory studies. (Photo by Edward Schafer)

New York: In 32 fields near Rochester, fewer sweet corn ears (2.5%) were damaged by birds in the 16 fields treated with Avitrol than in the untreated (control) fields (6.6%). Centimeters of trim, the length of the damaged portions of ears that would have to be removed before processing the damaged corn, also were less in the treated field (4.8 cm/40 ears vs. 10.1 cm), as were the row-centimeters of damaged kernels (20.9 row-cm/40 ears vs. 52.8 row-cm). Of the three differences, only the percentage of ears attacked was statistically significant at the 0.10 level. The 32 fields were assigned to one of two blocks: (1) fields with Mellogold, a variety reputedly very susceptible to bird damage, and (2) fields with other varieties of sweet corn. Within the Mellogold block, no statistically significant differences were found between the treated and untreated fields for any of the damage criteria. Within the "other varieties" block, treated fields had a significantly lower percentage of ears attacked than did the controls; centimeters of trim and row-centimeters of damaged kernels were less in treated than in untreated fields. Bird numbers were a little higher in untreated than in treated fields, and, concurrent with damage, they decreased drastically during the last 7 days of the 4-week test.

The small differences in damage levels between treated and untreated fields may be attributed, in part, to delays in getting the initial treatments on the fields, to the generally

low level of bird pressure, and to the extreme variation in damage among fields—three untreated fields had no damage.

Ohio: Treatments of Avitrol were applied to fields of sweet corn every 4 days beginning 9-12 days before harvest. Statistically, no significant difference was found in mean percentages of ears opened, row-centimeters of damaged kernels, or centimeters of damage to be trimmed from the ends of damaged ears between 14 treated and 15 untreated fields. Although harvest dates of the 29 fields were spread over a 35-day period from 6 August to 9 September 1974, important bird damage occurred only to fields harvested 13-19 August, when five untreated and three treated fields were heavily damaged (i.e., at least 20% of the ears were attacked by blackbirds).

In searches for dead birds, 11 blackbirds and 14 nontarget birds were found. The nontarget birds were seven

song sparrows, one savannah sparrow, five unidentifiable sparrows, and one indigo bunting. Ten of the 12 birds suitable for autopsy contained cracked corn bait.

These data indicate that a rate of application of Avitrol greater than the 1 pound per acre used for field corn may be necessary to protect sweet corn, and that there may be greater utilization by birds, and thus greater hazard to nontarget species, in sweet corn than in field corn.

Maryland: The test of Avitrol in this State was conducted from 27 July to 9 September 1974 in an area of historically severe bird damage to sweet corn. Eight of 16 fields, ranging in size from 13 to 24 acres and located within an area 6 miles in diameter, received treatment four times beginning 10 days before anticipated harvest. The percentages of ears damaged (7.9) and of trim required in processing (1.8) in the treated fields were twice those in the control fields (3.9 and 0.8). Thus, the efficacy of



Blackbirds in large flocks of several species may cause damage to cereal grains and other crops and become a nuisance in fall and winter roosts. The scene above is a grain sorghum field in South Dakota. (Photo by Gary Zahm)

Avitrol was not demonstrated in this test.

In daily 10-minute observations at each field, nearly twice as many blackbirds were seen in the treated fields as in the controls (28.5 birds per observation vs. 15.9); this correlates closely with the damage findings. This population may have been too low for the bait to have been effective.

Although Avitrol was not uniformly and clearly effective in controlling blackbird damage to sweet corn in New York, Ohio, and Maryland, data given in the previous section demonstrates its efficacy in Wisconsin and Idaho.

Tests of the efficacy of methiocarb in protecting field corn sprouts from blackbird damage.—A test was performed 21 May to 6 June at the Pungo National Wildlife Refuge, N.C., where 8 of 16 5-acre fields were randomly selected for a 0.5% hopper-box treatment of field corn seed with methiocarb, a candidate chemical bird repellent. Only one-half the number of corn sprouts (2.3 per 200 feet of row) were destroyed by birds in the treated fields than in the untreated fields (4.3 sprouts). This small amount of damage probably resulted from light and scattered bird pressure and was largely responsible for the inconclusive results. In daily morning counts, the average number of blackbirds observed per field before sprout emergence was less in treated fields than in untreated fields; after sprout emergence the average number of blackbirds was about the same in the two types of fields.

Methiocarb significantly reduced bird damage to sprouting field corn in 5-acre fields at Bombay Hook National Wildlife Refuge, Del. Eight of 16 5-acre fields were randomly selected for a 0.5% hopper-box treatment. Only one-tenth the amount of damage occurred in treated than in untreated fields (0.6% of the sprouts uprooted in treated fields vs. 5.7% in untreated controls). Moreover, in morning observations for 5 days following sprout emergence, common grackles, the predominant species, were seen in greater numbers on the untreated fields than on the fields planted with methiocarb treated seeds.

Methiocarb significantly reduced bird damage to sprouting field corn in 5-acre fields in Onondaga County, N.Y., where treatment was randomly assigned to 8 of 16 test fields. Damage in untreated fields was 28 times that in treated fields (2.8% of sprouts destroyed in untreated fields compared with 0.1% in treated fields). This reinforced results from the previous year's test, using 2-acre fields in the same area, when 25 times as much damage occurred in untreated fields as in treated fields. In both years, methiocarb was applied to seed corn at the 0.5% level as a hopper-box treatment in the planter. Similar numbers of blackbirds were observed in treated and untreated fields on the 2nd and 3rd days prior to sprout emergence. Thereafter, significantly greater numbers of

blackbirds were seen in untreated fields than in treated fields. There was no significant difference between treated and untreated fields in the observed number of birds other than blackbirds.

The data from Delaware and New York will be used to support registration of methiocarb for use in protecting field corn sprouts from bird damage.

Degradation of methiocarb following rice-plot application.—In Arkansas, 3 weeks after treatment of milk-stage rice with methiocarb, residues of the chemical were not detectable in panicle (grain cluster) or soil samples, and barely detectable in irrigation water. Methiocarb was applied at 2.8 pounds per acre to the plots at the bird-susceptible stage of growth, and periodic samples were taken to monitor breakdown of the chemical. Residues in all substrate samples dropped rapidly after the 1st week following treatment. If found to be efficacious and environmentally safe, use of this material would reduce late-summer blackbird depredations on the rice crop.

Estimating bird damage to sunflower heads.—In a laboratory test, four observers using the visual method overestimated true loss of seed from sunflower heads by an average of 0.5-2.0%, regardless of the level of loss. When they used the template method, the loss was underestimated, averaging less than 1% at low levels and greater than 5% at high levels. Variation among observers was slightly less with the template than with the visual method. Also, in field tests, use of the template method resulted in underestimation. The visual method was more efficient; about 3.3 times more heads could be assessed for damage per hour than with the template method. Overall, the visual method appears to be the better of the two in estimating damage to sunflower heads.

Red-winged blackbird reproductive rates in marsh and upland habitat.—Investigators have inferred that reproductive success is lower for red-winged blackbirds in upland than in marsh habitat. They have noted that factors such as the percentage of active nests that were successful, the number of young fledged per successful nest, and the number of young fledged per unit area have tended to be lower in upland than in marsh habitat. However, a true measure of reproductive success is the number of young fledged per territory. In a northern Ohio study, Service biologists estimated that an average of 5.5 young were fledged annually in each redwing territory in an old-field habitat in 1973-74. This estimate of reproductive rate, apparently the first reported for redwings nesting in upland habitat, is as high as, or higher than, four of five published estimates for redwings nesting in marsh habitat.

Although the redwing traditionally has been considered a marsh-nesting species, recent Service research shows that the majority of redwing territories are located in upland habitat in the Midwest. The present study indicates



Bird damage to a sunflower field can be measured by comparing the yield of completely protected (netted) heads with unprotected ones. Also, accuracy and efficiency of methods for visually estimating loss can be ascertained. (Photo by A. R. Stickley, Jr.)

that a territorial male in upland habitat will contribute, on the average, at least as many fledglings to the postbreeding population as will a territorial male in marsh habitat. Thus, any future population management plans developed for reducing redwing numbers in the Midwest should focus primarily on breeding populations in upland habitats.



Recording the heart beat of a blackbird by radiotelemetry. The system, which is being developed, will be used by biologists of the Patuxent Center to evaluate methods of stressing birds in a roost. (Photo by Paul Lefebvre)

Chemicals from dense populations of white-footed mice may inhibit maturation of young.—More than 75% of young white-footed mice, constantly exposed to the urine and feces from crowded populations of their own species, fail to reach reproductive maturity compared with young not so exposed. A Service researcher at Patuxent's Pennsylvania Field Station has been studying the stimuli and mediation of the inhibition of reproductive maturation of young animals that occur at high densities in various rodent species. Several indices of reproductive maturation (age at first estrus; ovary, uterus, and testes weights; and sperm counts), indicate that some stimulus, probably chemical, from the urine and feces of the crowded animals results in impaired reproductive maturation of young exposed to the stimulus. Since the inhibition seems to result from a chemical stimulus, it may be one that can be used in the future to affect reproduction in rodent species that cause agricultural damage.

ENVIRONMENTAL CONTAMINANT EVALUATION

Denver Wildlife Research Center

California brown pelicans recover as DDT-DDE contamination decreases.—DDT-related reproductive problems in California brown pelicans have been most acute in the northern parts of the pelican's range at Anacapa Island, Calif., and Isla Coronado Norte, Baja Calif. The major source of contamination, waste discharged from a

DDT manufacturing plant, was stopped in 1970. Productivity in these two colonies has improved significantly since 1971, though still about 30% too low for population stability. Early reports in 1975 indicated continued improvement in productivity. The numbers of adults breeding each year probably reflect food supplies and recruitment from more successful colonies to the south, but improving fledging rates (up to 0.9-1.1 young per nest in

1974-75) denote improved eggshell condition and better egg survival concomitant with the declining DDE contamination. Low residues of other contaminants such as dieldrin, mercury, lead, and cadmium did not change over the same period or were not related to eggshell thinning.

Food restriction intensifies reproductive effects of DDE in birds.—The productivity of brown pelicans in the Gulf of California off Mexico during the last 5 years has averaged less than 1.0 fledged young per pair. Existing data on mortality rates for the species suggest that 1.2-1.5 young per pair is necessary to maintain the population. The low productivity was due primarily to two types of reproductive failure: during 2 of the 5 years, 50% or more of the adults did not come to the colonies to breed, and each year 10-95% of the adults that did nest deserted their eggs or young. At Isla San Lorenzo Norte, direct observations, supplemented by continuous time-lapse photography dur-

ing the breeding season, have documented the reproductive behavior, nest attentiveness, and chronology of nest desertion. These and other data suggest that the inadequate productivity was caused by two interrelated factors—fluctuations in food availability and DDE residues carried by adults.

In 1974, laboratory studies with ring doves were begun to investigate the simultaneous effect of food deprivation and DDE on reproduction in a species with a reproductive strategy similar to that of the brown pelican. In the first of a series of experiments, groups of ring doves were fed either untreated diets or diets containing 100 ppm DDE for 3 weeks, followed by amounts of untreated food totaling 100, 90, 80, or 70% of their normal intake beginning 2 weeks before they were paired for reproduction. This trial was designed to test effects of DDE on reproduction and to explore the question of why some adult pelicans do not



California brown pelicans "posture" as they choose a nest site and establish a pair bond. Nesting success has improved greatly since DDT use has been restricted. (Photo by James Keith)

breed in certain years.

Food restriction alone and with DDE body residues caused a decrease in the intensity of reproductive behavior during the first 21 days after pairing, but effects were greater in the birds carrying DDE residues at a given level of food restriction. Egg laying was also seriously impaired by some treatments. All pairs on the 100% diet produced eggs, regardless of DDE exposure. Of the pairs on the 90% diet, 75% not receiving DDE laid eggs, but none of the DDE-exposed pairs produced eggs during the 72-day trial. On the 80% diet, only one non-DDE pair laid eggs and none of the DDE-exposed pairs laid eggs.

A productivity index was calculated for each pair from the total daily number of eggs and young that were present in the nest during the 72-day trial. Average productivity indices for treatment groups were:

		Food quantity (% of normal intake)			
		100%	90%	80%	70%
Untreated pairs		126	50	8	0
DDE-treated pairs		98	0	0	0

The results of this trial demonstrated that DDE residues in birds can have a drastic effect on reproductive behavior and performance when their food supply is restricted by as little as 10%.

Dietary methyl parathion reduces reproduction in ring doves.—To investigate the reproductive effects of methyl parathion, a widely used crop pesticide, ring doves were fed diets containing 15, 30, and 60 ppm (parts per million) during the reproductive cycle. One of three groups at each treatment level was treated: (1) throughout the total reproductive cycle, (2) after laying of the first egg, and (3) after hatching of the first egg. The 15-ppm diet caused a slight reduction in the number of young per pair raised to 21 days of age for the group that was treated after laying their first egg. Among doves on the 30-ppm diet, the greatest reduction in young raised was in the group treated after the first egg was laid; the reduction was nearly as great in the total treatment group and moderate in the group treated after the first egg hatched. In the three groups fed the 60-ppm diet, the only pair that raised young was one treated after their eggs hatched.

These results indicate that methyl parathion can adversely affect bird reproduction at 30 and 60 ppm and may have some effect at 15 ppm. Contamination levels of 15-30 ppm are not uncommon in the field, but exposure patterns for many species of wild birds may differ from those in this study. The degree of reproductive effect that parathion has on wild populations of birds in sprayed habitats is not known, but this study shows that parathion could be a problem under some conditions.

Toxicity and pathology of dioxin in ring doves and mallard ducklings.—Since 2, 3, 7, 8-tetrachlorodibenzo-

p-dioxin (TCDD) and other chlorinated dioxins are present in nearly any product, such as 2, 4, 5-T, that contains or is manufactured from technical chlorinated phenols, these compounds are potential contaminants in the environment. Because TCDD is reported to be extremely toxic, experiments were conducted to determine its effects on birds.

Mallard ducklings were given a single oral dose of TCDD at 4, 12, 36, or 108 µg/kg of body weight without showing observable changes in growth or food consumption, or in gross pathology. Ring doves were given single oral doses of 4, 12, 36, 108, 324, or 810 µg/kg. During the first 3 weeks after treatment the birds that received more than 36 µg/kg lost up to 25% of their weight and ate less feed than control birds, but none died. After 3 weeks, these birds began to eat as much as, or more than, the controls and gained weight. However, necropsy revealed that all the treated doves, including those in the lowest dose group, had enlarged livers. The livers of birds given 108 µg/kg were twice as large as those of controls.

Since the LD₅₀ of TCDD is about 2 µg/kg for guinea pigs and 100 µg/kg for mice and rats, these results suggest that birds may not be as susceptible to TCDD as mammals. Further tests will be made to confirm the strength of the TCDD used and toxicity to other species of birds.

Insect sex attractants not toxic to birds.—Tests with two insect pheromones showed them to be essentially nontoxic to mallards and bobwhite quail. The two compounds were grandlure, a boll-weevil sex attractant, and disparlure, a gypsy moth sex attractant. Each was fed at dietary concentrations up to 5,000 ppm to mallard ducklings and bobwhite quail chicks under the standard protocol for the 8-day LC₅₀ (the concentration of a toxic



Captive ring dove at nest. Ring doves are convenient experimental birds for testing the effects of pesticides on birds. (Photo by Milton Friend)

chemical that kills 50% of the experimental animals in 8 days). Neither compound produced mortality or caused clinical sign of intoxication or gross pathology. Food consumption for all treated diets appeared to be normal throughout the 8-day studies, and weight gains of treated birds were similar to those of control birds. These materials appear to be much less hazardous to wildlife than the chemical insecticides they may replace.

Blood residues of DDE, PCB, and dieldrin index exposure levels.—Studies in 1973 showed that DDE residues in the blood serum of mallards were highly correlated with DDE residues in the fat of the same birds, indicating that blood is a useful sample material for monitoring DDE exposure in addition to the traditional fat or whole-body composites. Blood sampling has the major advantage of not requiring the test animals to be killed; this greatly increases the species and numbers of animals that can be monitored and permits repeated sampling from the same individuals. To determine if the relationship shown for DDE holds also for other common organochlorine pollutants, a study was conducted in which mallards were fed a mixture of three such compounds.

Adult mallards were fed diets treated with a combination of DDE, a polychlorinated biphenyl (PCB), and dieldrin for 2 weeks. Blood serum, fat, and whole-body composites were collected for 112 days after treatment and analyzed for residues. For all three compounds, correlations were very similar for blood vs. whole body and fat vs. whole body; overall correlation coefficients (r) were 0.77 and 0.80, respectively, for DDE, 0.83 and 0.82 for PCB, and 0.89 and 0.89 for dieldrin for both sexes and all sampling periods. Both correlations were stronger in females than in males for all three compounds. These data indicate that blood is as suitable as fat for predicting whole body residues of DDE, PCB, and dieldrin in adult birds, and the relationship may hold for organochlorine compounds in general.

Kestrels get DDT from tussock moth spray in Pacific Northwest.—In 1974, when the U.S. Forest Service sprayed DDT on 427,000 acres of forested lands in the Pacific Northwest for tussock moth control, the Fish and Wildlife Service began a wildlife evaluation program centered on raptor populations in and near the spray areas. Although the impact of DDT on raptor productivity will not be fully understood until after one or more breeding seasons, the technique of taking small blood samples for residue analysis permitted a rapid assessment of the uptake of DDT in a kestrel population. (Earlier laboratory studies with mallards had shown that DDE residues in serum were highly correlated with those in fat, the traditional sample material.)

Analysis of blood samples demonstrated that wild adult kestrels, caught and released in or near the 1974 spray

areas, had DDE residues similar to prespray background levels. A few birds caught next to an Idaho heliport had higher DDE residues than the others, and some also showed residues of dieldrin and hexachlorobenzene, a chemical used on wheat seed. After the spray program, DDE concentrations in the blood depended on the distance from the spray areas that the birds were captured. There appeared to be no buildup of DDE in kestrels 6 miles or more from the spray area. DDT itself was found in the sera of two kestrels 4 days postspray; after 1 week, DDT was apparently metabolized to DDE in all birds.

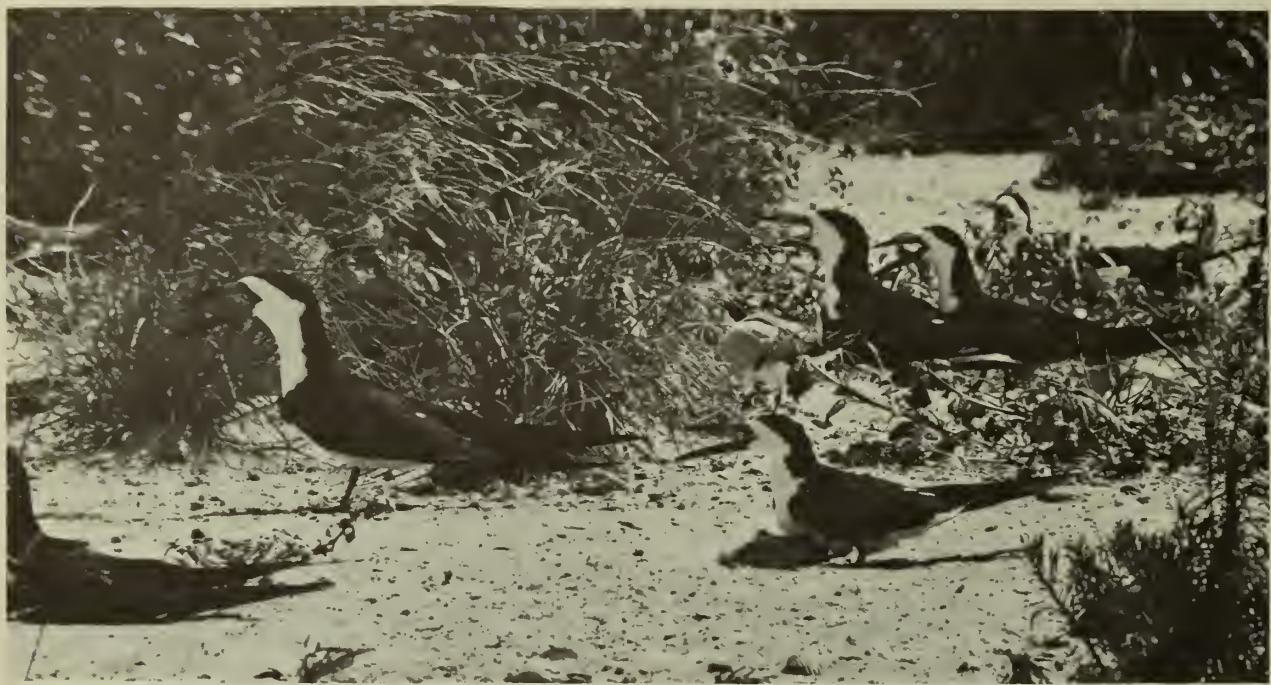
Wide-area malathion spraying in Nebraska.—A study of low-volume blanket treatment of irrigated cropland with malathion by entomologists of the University of Nebraska to control the western corn rootworm and other crop pests was reported in a previous annual report, "Wildlife Research in 1971" (page 49). Biologists of the Fish and Wildlife Service and the Nebraska Game and Parks Commission cooperated in monitoring the effects of the treatment on farm wildlife, with emphasis on bird populations.

The entomologists' initial conclusion was that wide-area control of crop pests was both operationally and economically feasible. Although the limited effects on birds observed during this study were not sufficient to deny this conclusion, they did indicate a decrease in environmental quality. After long discussions and deliberations, the research entomologists agreed that the concept of wide-area spraying on croplands was unnecessary and ecologically unacceptable. More recently the University's economic entomologists have changed their pest control philosophy from reliance on chemicals alone to integrated methods emphasizing pest surveys by experienced checkers, cultural methods, and minimal use of selective pesticides. This experience demonstrates the importance of cooperative field investigations in reducing contamination of the environment with pesticides.

Fish-Pesticide Research Laboratory

Acute toxicity of chemicals.—Basic acute toxicity tests were performed by biologists of the Fish-Pesticide Laboratory and its field stations on 48 chemicals. Although most were herbicides and forest insect control agents, the list included several industrial chemicals, one plant growth regulator, and one insect growth regulator. All of the test chemicals were selected because they have known or suspected potential for entering aquatic ecosystems by intentional application, or inadvertently through surface runoff, effluent discharge, or accidental spill.

Most toxic of the chemicals tested were DDT, Guthion, and leptophos (an experimental forest insecticide) which had 96-hour LC₅₀'s (the concentration lethal to 50% of



Black skimmers (top) and roseate spoonbills (bottom) on the U.S. coast of the Gulf of Mexico. These are among several species that are being checked annually to detect the effects of environmental pollutants on coastal birds. (Photo by Kirke King)

the test animals within 96 hours) of less than 10 µg/l (or ppb). Matacil is similar to Zectran and is being considered for control of forest insects in northeastern United States; however, the 17% liquid concentrate formulation of Matacil, which has a 96-hour LC₅₀ of less than 100 µg/l, appears to be considerably more toxic than Zectran. Two other candidate forest insect controls, Orthene and TH-6040, were relatively nontoxic (96-hour LC₅₀'s exceeded 100,000 µg/l). Of the industrial chemicals tested, the predioxin, chlorinated phenoxyphenol, was the most toxic, with a 96-hour LC₅₀ between 100 and 1,000 µg/l; 2-ethylhexanol, *n*-butanol, and monoethanolamine were relatively nontoxic. Most of the herbicides tested had 96-hour LC₅₀'s above 1,000 µg/l, but two 2,4-D esters—Dinitramine and Hydrothol 191—had LC₅₀'s between 100 and 1,000 µg/l.

Biologists recognize that physical and chemical characteristics of the water affect the toxicity of pesticides and other chemicals. Characteristics such as temperature, pH, and water hardness may work independently or together to modify chemicals or control their rate of uptake by fish. For this reason, initial laboratory toxicity tests of a chemical are usually performed under prescribed "standard conditions" pH, 7.2; water hardness, 40 mg/l; and temperature, 10-12° C for salmonids and 20-22° C for warmwater species). During the year, Laboratory researchers tested 14 pesticides in both coldwater and warmwater habitats. The insecticides Guthion, leptophos, and Imidan, and the herbicide diuron were considerably more toxic at 25° C than at 5° C. Chemicals whose toxicities were not greatly influenced by temperature included the herbicides picloram, dinoseb, 2,4-D acid, 2,4-D dimethylamine salt (DMA), 2,4-D butyl ester (BE), 2,4-D propylene glycol butyl ester (PGBE), and glyphosate (isopropylamine salt); and the insecticide toxaphene.

Alkaline pH increased the toxicity of Matacil, picloram, and Emulsamine E 3 (2,4-D formulation), but did not affect toxicities of 2,4-D BE, diuron, Eptam, Sumithion, or toxaphene. Chemicals less toxic in alkaline than in acid water were Guthion, Imidan, dinoseb, 2,4-D DMA-4, 2,4-D PGBE, and 2,4-D acid.

Forest insecticides.—Extensive damage to forests by defoliating insects has become a problem of National significance. The tussock moth, spruce budworm, and gypsy moth have caused annual losses estimated to exceed 2.4 billion cubic feet of lumber. Reforestation of the affected areas is expected to take more than 20 years.

After cancellation of the registration for DDT, the Fish-Pesticide Laboratory cooperated extensively with the U.S. Forest Service in toxicity tests of nonpersistent chemicals with potential for control of forest pests. Matacil, Sumithion, Sevin, Dylox, Orthene, and TH-6040 (an insect growth regulator) were tested against

coho salmon, rainbow trout, Atlantic salmon, brown trout, brook trout, carp, fathead minnows, channel catfish, bluegills, daphnids, scuds, and midges. The toxicity of all of the compounds to fish was less than 0.001 that of DDT. However, Matacil (17% liquid concentrate) was about 100 times more toxic than its technical form and could be a serious hazard to fish. The chemical TH-6040 was not toxic to fish, but 48-hour EC₅₀'s (effective concentration) for daphnids and scuds were between 10 and 40 µg/l. This compound was not acutely toxic to midge larvae (48-hour EC₅₀, 560 µg/l), but chronic exposures showed the larvae to be sensitive to concentrations between 2 and 6 µg/l.

The toxicity of some forest insecticides to trout may increase if the fish contain residues of PCB's (Aroclor 1254). The carbamate insecticides such as Sevin and Matacil are up to twice as toxic to brook trout that contain Aroclor 1254 residues of 1.5 µg/l as to those free of the residue. However, the susceptibility of brook trout to the organophosphate insecticides, Dylox and Sumithion, is not affected by the presence of Aroclor 1254 residues.

Tussock moth control in 1974 increased DDT residues.—In samples of fish collected from the same locations before and after the application of DDT to certain areas in the Pacific Northwest to control the tussock moth, DDT residues increased ten-fold after the spraying. Surprisingly, toxaphene residues ranging from 0.5 to 6 µg/g were present in most of the samples. Toxaphene is usually detected in fish collected from the southeastern United States where cotton is grown; the origin of the toxaphene in the Northwest is not yet known.

Relation of chemical sprays to Atlantic salmon.—More than 2 million acres of forest were scheduled to be sprayed for spruce budworm in 1975. Much of the budworm-infested area is in Maine and includes habitat vital to Atlantic salmon. Populations of salmon have declined drastically over the years and concerted efforts are underway to identify the factors causing this decline. Contamination of the habitat by pesticides and other chemicals is suspected to be a contributing factor.

Contaminants of particular concern to fishery biologists include residues of DDT and PCB's (Aroclor 1254) already present in salmon; Guthion (organophosphate insecticide), which is used in blueberry culture; forest insect control chemicals; and possible interactions between various contaminants. The 96-hour LC₅₀'s (µg/l) for fingerling Atlantic salmon were 1.8 for *p,p'*-DDT, 96 for *p,p'*-DDE, 2.7 for Guthion, and 3.9 for leptophos. The toxicities of forest insecticides to be used in 1975—namely, Sumithion (fenitrothion), Dylox, Sevin, and Matacil—ranged between 1,160 and 7,600 µg/l. In general, invertebrates such as daphnids, scuds, mayflies, stoneflies, and midges are about 100 times more sensitive

than salmon to these compounds. Scuds and daphnids were sensitive to Guthion at concentrations below 1 $\mu\text{g/l}$. Although Atlantic salmon fry exposed to Aroclor 1254 concentrations of 0.14 to 1.14 $\mu\text{g/l}$ for 90 days accumulated residues of 4.8 to 60 $\mu\text{g/g}$, the chemical did not influence development, growth, or survival.

Limnological data on streams in the treated areas show that waters range from relatively cool and neutral to warmer and more alkaline (17° C, pH 8.5). Studies in progress show that Sevin is more toxic to Atlantic salmon in warm, alkaline water than in cool, neutral water, and that Sumithion is twice as toxic at 12° C than at 7° C.

Some chemicals considered in these investigations show toxicological interactions. Mixtures of Guthion and Dylox were synergistic in Atlantic salmon fingerlings, as were mixtures of DDT and Dylox. However, fingerlings with tissue residues of 1.5 $\mu\text{g/g}$ DDT (and its analogs) were no more susceptible to the Guthion-Dylox mixture than fish were without the residues.

In summary, barring accidental spills or excessive application rates, the control program for spruce budworm should not have a direct adverse impact on young Atlantic salmon. Crustaceans and insects, however, are susceptible to all of the chemicals being applied and mortalities of aquatic invertebrates in treated areas are probable. Also, the liquid concentrate formulation of Matacil, which is considerably more toxic than technical Matacil, could cause some fish mortality. Populations of aquatic invertebrates in the treated areas should be monitored for declines and repopulation. A prolonged shortage of food could affect the condition of young salmon and resident species of fish.

Chemical for processing oil shale poses hazard to trout.—If the shale oil industry will produce 1 million barrels of oil per day as now envisioned, the chemical monoethanolamine will be used at a rate of 2 million pounds per year in the oil upgrading and gas processing sections. In spent form, monoethanolamine is a sludge-like material that is highly soluble in water; it is to be disposed of within the spent shale piles. Leaching or erosion could contribute significant amounts of this chemical to aquatic habitats.

Because the shale oil industry is in the western United States, and because salmonids support important western fisheries, monoethanolamine was tested against brook trout. Two-year-old brook trout were continuously exposed to concentrations of 0.6-20 mg/l, beginning 4.5 months before the fish spawned. The fish were brought to spawning condition by manipulation of temperature and photoperiod. Adult growth and survival were not affected by monoethanolamine, but egg viability and hatchability were significantly reduced in fish exposed to 1.6-20 mg/l of the waste chemical. Growth of fry was inhibited by

concentrations of 10 and 20 mg/l. In addition, pH and alkalinity of water increased slightly, due to the trapping of carbon dioxide by monoethanolamine. These water quality changes may influence the bicarbonate buffering capacity of waters in the western United States.

Although the ineffective concentration of monoethanolamine (0.6 mg/l) is much higher than that usually encountered among pesticides, the amount that will be disposed of is large. Consequently, a thorough study of monoethanolamine leaching from spent shale piles should be undertaken.

Environmental control systems improve channel catfish culture.—Tests of chronic toxicity are usually performed in controlled environments, and these systems are becoming widely recognized as important tools in assessing biological impact of environmental contaminants. Chronic tests involve exposures of fish to low concentrations for a whole or partial life cycle, including prespawning and spawning adults, eggs, and young. Subtle effects of low concentrations of contaminants may not show up except in reproductive success or fry growth. Control of light, temperature, and other factors is important in such tests to insure natural spawning in the laboratory. To date, laboratory systems have been developed for brook trout, fathead minnows, bluegills, and flagfish. Similar techniques have not been available for natural spawning and rearing of channel catfish in the laboratory.

At the Fish-Pesticide Laboratory natural spawning techniques for channel catfish were recently developed in conjunction with studies of the chronic effects of toxaphene on the species. The system consists of 12 stainless steel tanks 1.8 m long \times 0.9 m wide \times 0.6 m deep, containing water to a depth of 0.45 m. Water was delivered to each tank at a rate of 1.6 liters per minute. Twelve 2.5-year-old fish were placed in each tank, and this number was further reduced to six—two males and four females—just before spawning. The fish averaged 1.2 kg each and the initial stocking rate was equivalent to 87,000 kg/ha. The fish were brought into spawning condition by manipulating day length and temperature from February to May. By May, 42 females were available for spawning. Of these, eight did not mature sexually and five matured but did not spawn. The remaining 29 females spawned naturally and produced 262,000 eggs, of which 90% hatched. Growth of the fry was faster than that reported for most routine cultural operations.

In later studies, biologists attempted to advance the spawning time to February but the study was lost due to failure of a water-supply well. Nevertheless, the ovaries of these catfish were developing rapidly by the end of January. Theoretically, if the fish spawned in January or February, 5- to 10-cm fingerlings could be produced for late spring stocking in ponds and, depending on tempera-

ture and food supply, these fish could conceivably attain catchable or marketable size by the end of the first growing season.

Toxaphene impairs growth and development in channel catfish.—Toxaphene is an organochlorine insecticide used mainly in the southeastern United States for controlling most major pests on cotton. As a result of its extensive use, residues of toxaphene ranging as high as 48 µg/g have been found in fish from this region by cross-check analyses for the National Pesticide Monitoring Program. The effects of toxaphene on channel catfish were investigated because of the high sport and commercial importance of this species.

Adult (2.5-year-old) channel catfish were exposed continuously to toxaphene concentrations of 0, 24, 44, 84, 224, and 535 ng/l for 100 days before spawning. After the fish had spawned, the fry that hatched were exposed for an additional 90 days. Toxaphene did not inhibit growth or spawning of adult catfish or percentage hatch of the eggs. However, within 30 days after hatching, fry exposed to toxaphene concentrations of 224 and 535 ng/l showed significantly increased mortality and decreased growth. Toxaphene residues in these fry were 8 and 32 µg/g, respectively.

The proper ratio of collagen, calcium, and phosphorous is necessary for rigidity of bone, as well as normal bone development. Toxaphene concentrations of 44, 84, 224, and 535 ng/l significantly decreased collagen and increased calcium in backbones of fingerling catfish after 90 days of exposure. Residues in the affected fingerlings ranged upward from 3 µg/g. X-ray analyses of these fish revealed aberrations in backbone structure.

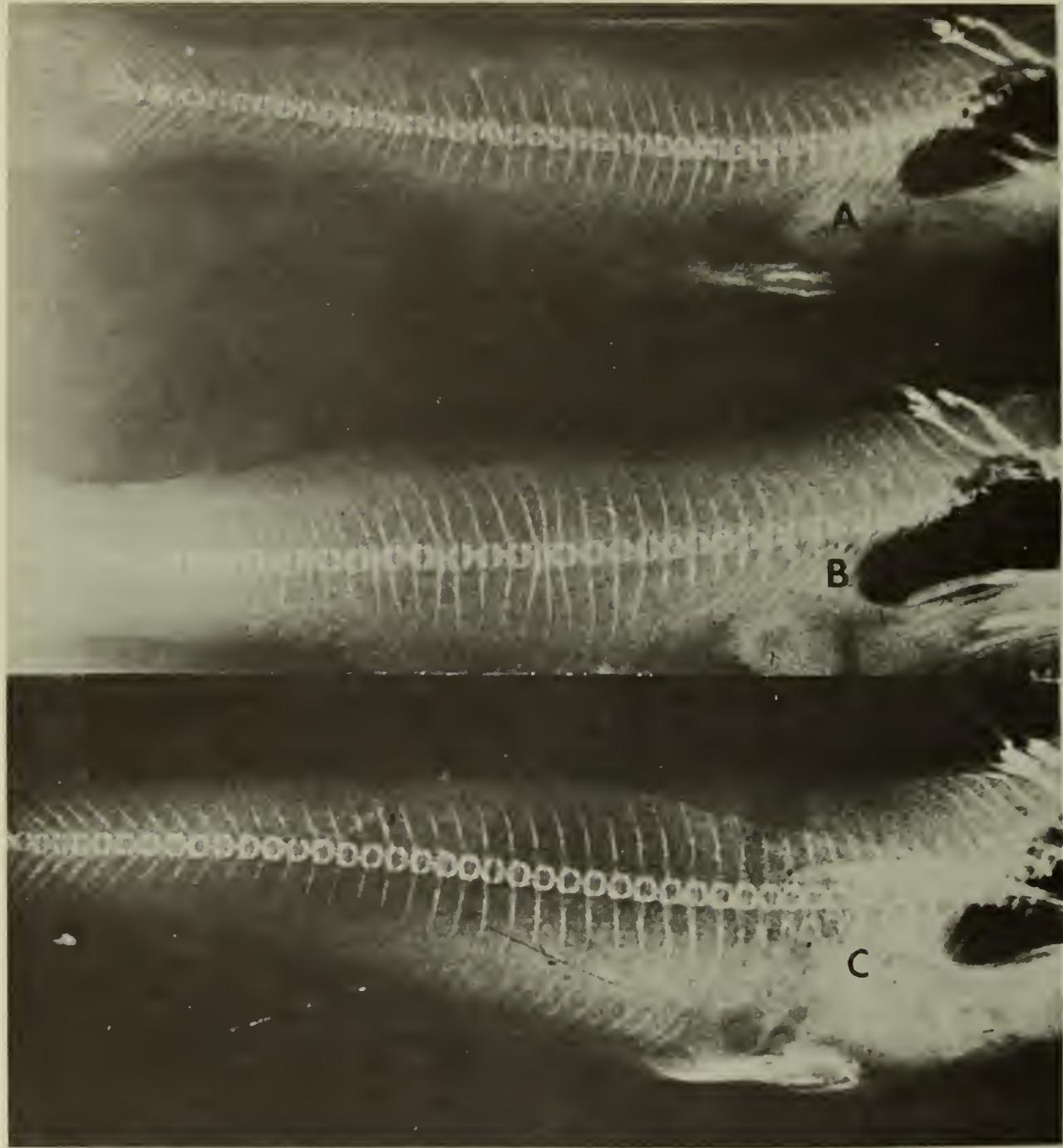
Rainbow trout sac-fry sensitive to plasticizer.—Di-2-ethylhexyl phthalate (DEHP) is a plasticizer used extensively in the manufacture of polyvinyl chloride resins. Residues of this chemical in sport and commercial fish have raised questions as to whether it may have subtle, sublethal effects. Biologists of the Fish-Pesticide Laboratory initiated studies to evaluate the effects of DEHP on hatchability of rainbow trout eggs, effects on growth and development of the fry, and the dynamics of the residue in both eggs and fry. Rainbow trout eggs were exposed to 3, 12, and 50 µg/l of ¹⁴C-DEHP for 12 days before hatching and the resulting fry to the same concentrations for an additional 90 days. After the first 6 days of exposure, the eggs absorbed or adsorbed total residues (mostly on the chorion) of 1.1, 3.5, and 6.1 µg/g from the respective exposure concentrations. The DEHP caused fry mortalities, but had no effect on hatchability of the eggs or on growth of surviving fry. Mortalities of 20-25% occurred among 5-day-old sac-fry that had been exposed to concentrations of 12 and 50 µg/l. Some fry exposed to 3 µg/l also died, but the numbers were not

statistically significant. Fry that died after 5 days in the two highest concentrations also contained a larger proportion of the parent DEHP residue than was found in fry that died during exposure to 3 µg/l. These findings suggest that the ability of sac-fry to metabolize DEHP was exceeded at the two highest concentrations. Histopathological examination of sac-fry showed that 3 µg/l caused focal areas of necrosis in developing liver tissue, whereas concentrations of 12 and 50 µg/l caused more severe reactions, with stromal damage as well as necrosis of the hepatocytes. Survivors of the DEHP exposures grew normally and exhibited no additional adverse histopathological effects on the liver. The evidence thus indicates that concentrations greater than 3 µg/l of DEHP in streams may seriously affect newly hatched salmonids.

Esters of 2,4-D affect young lake trout.—Cattle grazing and small grain crops are important in the agricultural economy of the intermountain West. These agricultural areas are interspersed with cutthroat trout habitat in upper watersheds and are common along rivers and reservoirs that support various salmonid fisheries at lower elevations. Recently the U.S. Forest Service has increased grazing allotments and the butyl ester (BE) of 2,4-D is being used to control sagebrush and encourage growth of cattle forage. The propylene glycol butyl ester (PGBE) of 2,4-D is used to control weeds in small grain crops. These compounds may enter salmonid habitats by way of spray drift or runoff. Little is known of their acute and chronic effects.

The 96-hour LC₅₀'s for 2,4-D BE to fingerling lake trout ranged between 640 and 880 µg/l, and for 2,4-D PGBE between 1,050 and 1,125 µg/l. Continuous exposures of fry to these compounds for 60 days showed that 60 µg/l of 2,4-D BE lengthened yolk sac absorption time and reduced survival and growth; 33 µg/l reduced growth; and 15 µg/l had no effect. The 2,4-D PGBE formulation lengthened yolk sac absorption time and reduced growth at 51 µg/l, but had no effect at 33 µg/l. Thus both esters of 2,4-D may have sublethal effects on young salmonids at concentrations that are only 0.05 of the acutely toxic concentration.

Rainbow trout fry avoid herbicides.—Herbicides are used extensively to control aquatic and ditchbank vegetation in and along the complex irrigation systems of the western United States. Many of these systems transport relatively cool water and, therefore, support trout fisheries in reservoirs and some connecting canals. Extensive plant growth in and along canals is a particularly acute problem because it restricts water flow and reduces volume of the canals. At present, herbicides are the most feasible and economical approach to controlling such plant growths. A number of chemicals of widely differing toxicity to trout are used or are being considered for this



Radiographs showing the effects of toxaphene on backbone structure of channel catfish: A, fish exposed to 535 ng/l; B, fish exposed to 44 ng/l; and C, an unexposed fish. (Fish-Pesticide Laboratory photo)

purpose. In general, chemical applications are made to main and lateral canals, and concentrations effective for plant control are diluted before treated waters are used in irrigation or are returned to streams and reservoirs. The effects of many of these chemicals on trout are not well

known. Presumably, however, if trout could detect these materials in water, they might be able to evade toxic concentrations, particularly in main and lateral canals, provided there is suitable habitat elsewhere. Nevertheless, continued avoidance of localized habitats in streams

and reservoirs receiving irrigation waters would essentially result in a loss of these habitats.

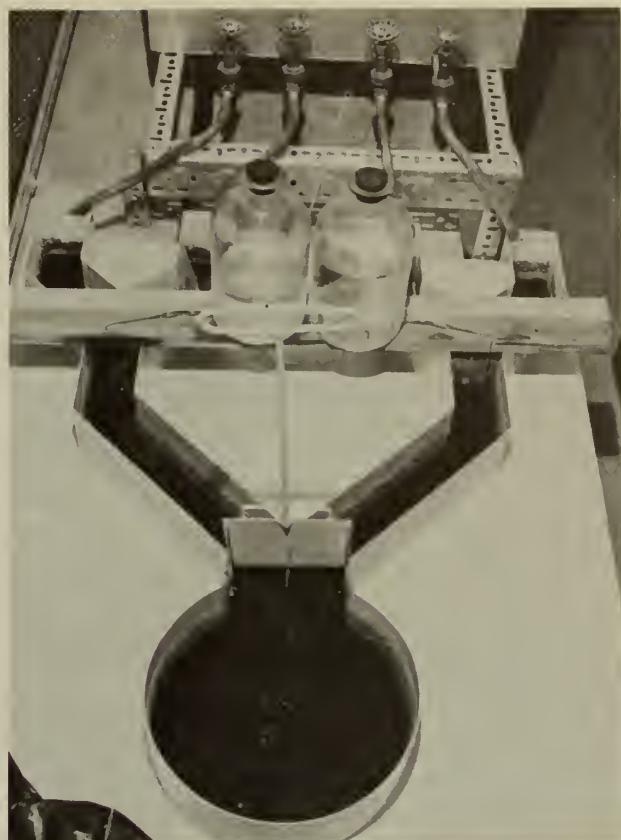
Other investigators have shown that both freshwater and marine organisms are able to detect and avoid various concentrations of certain organic and inorganic contaminants. Because trout may move to avoid herbicides used in irrigation systems, Fish-Pesticide Laboratory personnel initiated studies to determine sensitivity of rainbow trout to herbicides that are in use, or are potentially useful. Herbicides tested in a laboratory avoidance apparatus were 2,4-D DMA, Aquathol K, copper sulfate, dalapon, diquat, xylene, trichloroacetic acid (TCA), acrolein, and glyphosate (a new potential herbicide for emergent vegetation).

The lowest concentration of each herbicide tested that was avoided by rainbow trout fry was $0.1 \mu\text{g/l}$ for copper sulfate, $100 \mu\text{g/l}$ for TCA, and $10,000 \mu\text{g/l}$ for glyphosate, Aquathol K, and diquat. With the exception of copper sulfate, acrolein, and xylene, the fry did not avoid concentrations of the other herbicides below those expected to occur in, or recommended for application to, irrigation systems. All herbicides except acrolein were tested at sublethal concentrations; trout fry did not avoid acrolein before receiving a lethal exposure. The sensitivity of trout fry to copper sulfate was striking and it seems likely that they would leave habitats treated with this chemical, if possible. Although the fry avoided xylene concentrations of $100 \mu\text{g/l}$, they were attracted to concentrations of $10 \mu\text{g/l}$. Dalapon, 2,4-D DMA, glyphosate, Aquathol K, diquat, and TCA apparently would not cause direct mortality or avoidance when used as recommended.

Other studies with Aquathol K and glyphosate show that exposure of sexually maturing brown trout to these compounds does not inhibit gonad development. The exposures simulated applications for control of aquatic vegetation in irrigation systems. However, these compounds cause significant mortalities among rainbow trout eggs and fry exposed to higher-than-expected concentrations ($>10 \text{ mg/l}$ for 4 hours).

Degradation of herbicides.—The chemical identity of radioactive residues of ^{14}C -2,4-D DMA in fish has been resolved. Earlier studies with bluegills in outdoor plastic pools suggested that exposed fish accumulate radioactive metabolites. Identification of these metabolites was required by the Environmental Protection Agency (EPA) for establishment of 2,4-D residue tolerances in fish. This requirement could not be met, however, because of insufficient radioactivity in any one specific metabolite.

During the year, the exposure of bluegills in outdoor plastic pools was repeated, except that a greater ratio of ^{14}C -2,4-D DMA, with higher specific activity, was used. The results showed that 2,4-D molecules were broken



Avoidance apparatus used to test sensitivity of rainbow trout fry to herbicides applied to irrigation systems. (Fish-Pesticide Laboratory photo)

down in water, and that the resulting ^{14}C -fragments were taken up by bluegills and converted into natural biochemicals. Although most of the radioactivity was incorporated into amino acids of proteins, significant amounts of it were in free fatty acids and triglycerides. Some radioactivity was associated with glycogen and various Krebs cycle intermediates or free amino acids. These data were accepted by EPA and will be used to support petitions for aquatic uses of 2,4-D DMA.

Dinitramine is registered for use on cotton, soybeans, peanuts, and dry beans. It is quickly accumulated by carp and channel catfish after brief exposures (12 hours) to low concentrations (1 mg/l). When the fish were transferred to untreated water, neither species eliminated the chemical within 24 hours. Residues in carp, however, declined to less than 1 ppm in muscle (fillets), plasma, and bile after 7 days in fresh water. Biotransformation of dinitramine in carp occurred by a route that is uncommon in fish: Dealkylated dinitramine was found in the bile after the fish had been in fresh water 1 day, and after 7 days it was present in concentrations greater than the parent com-

pound. This metabolic conversion was confirmed by mass spectrometry.

"Accumulation index"—a red flag for natural resource managers.—Reports of the U.S. Tariff Commission show that production of synthetic organic chemicals has increased 1,200% since World War II. Also, between 1965 and 1973, production of pesticides and related products has grown at a rate of nearly 10% per year. The Nation's aquatic habitats are a repository for some of this chemical production. The extent of contamination is highlighted by EPA studies of the New Orleans Area Water Supply, which revealed the presence of more than 60 synthetic organic chemicals in water from the Mississippi River. The National Monitoring Program has shown that fish accumulate some of these chemicals at alarming rates. The consequence of such accumulations by fish are illustrated by the Minamata Disease (mercury) problem in Japan and the seizure by the Food and Drug Administration of PCB-contaminated coho salmon caught in Lake Michigan. These and other incidents point to the need for judging relative propensity of chemicals to accumulate in fish and other aquatic organisms.

Several years' research on a model laboratory food chain for estimating accumulation of chemicals by fish culminated in inclusion of the model in "Guidelines for Registering Pesticides in the United States," published by EPA (Federal Register, 40[123]:26906-26909). The model includes three trophic levels, is uncomplicated and economical, and is analogous to segments of natural ecosystems. Its use yields qualitative and quantitative data on chemical uptake by microorganisms, daphnids, and bluegills and on elimination and degradation over a 28-day period.

The relative propensity of synthetic organic chemicals to accumulate in aquatic ecosystems can be calculated from data obtained in food chain studies and expressed as an "accumulation index." The index is based on the amount of chemical taken up by fish as compared with accumulation of a chemical standard, such as *p,p'*-DDT, under similar conditions of temperature, exposure, biomass, and concentration. Data extracted from food chain studies completed at the Fish Pesticide Laboratory show that when uptake of DDT is used as unity (100), the index for hexachlorobenzene (HCB) is 43, and that for leptophos is 27. In contrast, di-2-ethylhexyl phthalate (plasticizer) has an index of 5 and the herbicide simazine has a value of only 0.05, indicating that these two compounds have a relatively low propensity for accumulating in fish tissue beyond the concentrations in water.

Supported by the Office of Toxic Substances of EPA, the Laboratory is continuing research on model food chains to examine reproducibility of the technique and to compare the results with those obtained by other inves-

tigators using more elaborate models.

Process for reclaiming Herbicide Orange filed for patent.—Herbicide Orange is a defoliant composed of 2,4,5-T and 2,4-D. The U.S. Air Force currently has 2.3 million gallons of this chemical mixture, which is in short supply and valued at millions of dollars on the domestic market. However, a significant portion of Herbicide Orange is contaminated by chlorinated dibenzo-*p*-dioxins. The dioxins are among the most toxic organic chemicals studied to date.

During the course of cooperative research with the Food and Drug Administration on sample-cleanup methods, chemists of the Fish-Pesticide Laboratory discovered that dioxins are selectively and irreversibly sorbed by coconut charcoal. Further experimentation showed that the method removes more than 99% of the dioxins from Herbicide Orange. The Department of the Interior has filed a patent outlining the process and describing the potential for dioxin removal from large volumes of Herbicide Orange. Commercial implementation of the process could mean substantial savings to the public, improve the safety of domestic supplies of 2,4,5-T and silvex, and save additional costs associated with destruction of the contaminated herbicide. A recent decision by EPA appears to require demonstration that cleanup of Herbicide Orange is not an acceptable alternative to high temperature incineration.

The U.S. Air Force is currently funding additional research on the cleanup of dioxin from this herbicide; the work is being conducted jointly by the Fish-Pesticide Laboratory and the Chemistry Department of the University of Missouri. Preliminary results indicate that dioxins absorbed on charcoal can be thermally degraded without volatilization from the charcoal. If these results are confirmed, the disposal of adsorbed dioxins will be greatly simplified.

Research begins on systems approach to field appraisals.—Management of natural and agricultural resources—for example, forest pest control, mosquito control, crop protection, and aquatic weed control—may have inadvertent or intentional impacts on the integrity of aquatic ecosystems. Disruption of complex interrelations may trigger secondary effects such as loss of habitat, deoxygenation, plankton blooms, and changes in species composition which vary in severity and duration. Therefore, choice of potential effects for measurement and prediction of disruptions in major ecological functions or processes is difficult.

Ponds at the Fish-Pesticide Laboratory have been used for a number of years to evaluate impacts of pesticides on selected segments of pond communities. However, emphasis is now being placed on a broader examination of limnological characteristics of the ponds. A systems ap-

proach is being tested on 12 ponds to analyze and relate temperature, light, turbidity, conductivity, NH_4 , NO_2 , NO_3 , PO_4 , pH, and redox potential of water and benthic mud with biological measurements. The biological measurements include primary productivity of planktonic and epibenthic algae, biomass estimates of rooted plants and benthic invertebrates, and quantitative and qualitative analyses of phytoplankton, zooplankton, and emergent insects. A concentration of 2 mg/l of 2,4-D DMA was applied to some ponds to induce an ecological impact. Statistical analyses will be used to construct a descriptive model of related variables, and these variables will be included in a theoretical model for initial predictions of effects on biological interrelations. The objective of this work is to identify major physical, chemical, and biological parameters that are most useful in anticipating the effects of resource management practices on pond communities.

Striped bass reproductive failures may be linked to contaminants.—Although striped bass have been propagated for a number of years, their culture has been plagued with intermittent, unexplained failures. A potential cause is contaminants. Therefore, Fish-Pesticide Laboratory chemists continued their cooperative research with Region 4 personnel to perform residue analyses on samples of striped bass brood fish, fry, and eggs collected along the East Coast. During the year, 99 samples of striped bass collected in North and South Carolina were analyzed. Residues of toxaphene, dieldrin, PCB's, and the *p,p'*-isomer of DDE, DDD, and DDT were found in almost all samples. In addition, *cis*-chlordane and benzene hexachloride residues were found in many samples. Some examples of the residue levels on a wet weight basis were: toxaphene, 0.1-4.1 $\mu\text{g/g}$; dieldrin, 0.01-0.12 $\mu\text{g/g}$; and *cis*-chlordane, 0.01-0.18 $\mu\text{g/g}$. Reproductive success, as estimated by percent cleavage of the eggs, ranged from 7.6 to 81.1%.

Automation and new analytical approaches enhance detection of environmental contaminants.—Demand for analyses of an expanding array of pesticides and industrial chemicals is a growing challenge to the Fish-Pesticide Laboratory's analytical staff. This demand is being met by development of further automation of analytical processes and construction of more sensitive instruments. First-stage automation of cleanup for pesticides in fish extracts through use of gel permeation chromatography (GPC) is being extended. Secondary cleanup columns are now required to further separate contaminants such as dioxins, dibenzofurans, and phenolic degradation products of forest insecticides. The secondary columns include other GPC resins, charcoal, Florisil, and silica gel; the complex switching of effluents from the primary GPC to secondary columns is controlled by a microcomputer.

New developments in the field of mass spectrometry have enabled analysts to detect, identify, and quantitate certain complex contaminants that heretofore were difficult, if not impossible, to examine by usual gas chromatography-mass spectrometry (GC-MS). The two newest mass spectrometry systems utilize chemical ionization (CI) or atmospheric pressure ionization for detection. We used CI-MS to make positive identification of toxaphene in fish from the southeastern United States, and in red-winged blackbirds. Some of the more than 150 components in toxaphene appear to be extensively metabolized in birds, but not in fish; mass spectra of toxaphene in birds are considerably different from those in fish. The ability of birds to partially metabolize toxaphene may explain differences in susceptibilities of fish and birds to this insecticide.

Patuxent Wildlife Research Center

Dieldrin residues high in eastern eagles.—Bald eagles are not common in the coastal southeastern States and reproductive success there has been poor. In 1964-72, a total of 17 eagles found dead in this area were analyzed for organochlorine chemicals. Dieldrin residues in brains of eight birds ranged from 3.6 to 11 ppm, levels that are hazardous and within the lethal range as determined in experimental studies. All contained a number of other compounds in sublethal amounts. Only 11 of 173 bald eagles from other areas of the United States had such high levels of dieldrin.

The frequency of high residues of dieldrin in bald eagles led investigators to question the ability of eagles to excrete this compound as readily as do other species. Pilot studies, in which the dissipation of a single oral dose of dieldrin was followed by the analysis of dieldrin in the blood, showed no change in 102 days, suggesting a very long retention time for this compound.

Bald eagle eggs transplanted.—For many years, bald eagles in Maine have failed to provide enough eaglets to maintain the population. High residues of organochlorines are believed to be a principal cause. In an effort to sustain a continuing population of eagles in the area, trial transplants were initiated in 1974. Two eggs from Minnesota nests were successfully placed in Maine nests and both eggs hatched. One eaglet died within 10 days but the other lived to the fledgling stage. The Maine eggs, which were removed to make space for the transplanted eggs, were not viable. Analyses showed high levels of DDE, dieldrin, and PCB's. DDE residues measured 20 and 35 ppm; dieldrin, 1.2 and 1.0 ppm; and PCB's 37 and 39 ppm. Small amounts of several other chemicals also were present.



Young bald eagle recently hatched (and removed from nest for photographing). Trial transplants of eggs and young of this species have been made to maintain populations in areas where natural reproduction has not been adequate, apparently because of pesticides. (Photo by Brooke Meanley)

Effects of disturbance on lethal residues of dieldrin in brain.—Red-winged blackbirds stressed by frequent disturbance during dosage died in a shorter time and had slightly higher levels of dieldrin in the brain than unstressed birds. Although aldrin, which metabolizes to dieldrin, was used for dosage, lethal levels of dieldrin in the brains did not differ from those found in birds killed by dieldrin. No aldrin was detected in the samples.

Azodrin and endrin were the most toxic of 131 pesticides tested.—Tests measuring the lethal dietary toxicity of 131 pesticidal compounds have been conducted with young bobwhites, Japanese quail, ring-necked pheasants, and mallards. Virtually all of the compounds have been used or are intended for use in the natural environment. Azodrin, an organophosphorus compound, was the most toxic chemical tested. Endrin, an organochlorine, was the second most toxic. Toxicities were measured by a statistically planned procedure that determines the concentration of chemical in the diet that will kill 50% of the birds in 5 days (LC_{50}). On this basis, the LC_{50} for azodrin was less than 10 ppm and for endrin was less than 20 ppm.

Endrin residues in the brain at death.—Residues of persistent organochlorines in brains are generally diagnostic of death. Recent work with endrin provided readings

for 12 individuals, including a broadwing hawk, three sparrow hawks, a screech owl, a barn owl, a cowbird, two red-winged blackbirds, and three white mice. The geometric mean for this series was 0.51 ppm (wet weight) with a 1 standard deviation ranging from 0.31 to 0.84 ppm. The overall range of residues was from 0.21 to 1.2 ppm. These data permit a judgment of the likelihood that endrin was responsible when animals are found dead in the field.

A point of importance is that one of the sparrow hawks was killed by eating mice that had been in the freezer for 2-4 weeks. This indicates that, although endrin is lost rapidly from living rats as the literature states, it does not break down rapidly in dead tissue. This point is supported by a preservation study made earlier at Patuxent, which revealed that minced flesh lost little endrin even when allowed to mold in the refrigerator.

Birds found dead with pesticide residues.—An adult female peregrine falcon, found dead at Pea Island National Wildlife Refuge, N.C., in March 1973, showed the typical emaciation of pesticide poisoning. Analysis of carcass and brain identified 10 organochlorine compounds in the carcass, eight of which were also in the brain. Dieldrin concentration in the brain was 5.4 ppm, within the range known to cause death by dieldrin poisoning. The concentration of DDE in the brain was 34 ppm and that of PCB's was 55 ppm, both well below lethal levels. Other chemicals were present in amounts below 0.5 ppm.

A loon found in a soybean field in Mississippi in December 1973 proved to contain 200 ppm of DDD in the brain, a concentration well within the lethal range of this compound. The brain also contained 130 ppm of DDE, 2.1 ppm of DDT, 8.7 ppm of DDMU, and 15 ppm of PCB's, levels not presumed to be lethal. A hydroxylated form of DDD not previously found in an environmental sample also was identified.

Secondary poisoning proven for endrin.—To learn if endrin used on forest seed caused secondary poisoning in predators, experiments were conducted by feeding hawks and owls on white mice that had been killed by eating endrin-treated longleaf pine seed. Three sparrow hawks and one broadwing hawk died within 3-12 days when fed these mice. One of the sparrow hawks died within 3 days after eating only 1.5 mice. It is clear that mortality could be expected in the field. This is supported by the finding of a dead sparrow hawk that contained endrin soon after an area in the South was treated operationally.

Owls were more resistant than hawks. A barn owl died only after 21 days, during which it ate approximately 48 treated mice. One screech owl rejected most treated mice, eating only 1.4 mice in 8 days. It was then given clean mice for 6 days, followed, again, by treated mice. It died



Barn owl guarding eggs in enclosure at the Patuxent Wildlife Research Center. Effects of environmental contaminants on bird reproduction are being evaluated in a series of experimental studies. (Photo by J. Maestrelli)

after 20 more days during which it ate approximately 16 mice. Another screech owl accepted treated mice readily and sickened only after 5 weeks. For 2 more weeks, it was given only clean mice and gradually ate more and more. It recovered, was returned to the colony, and took over a nest box from two other screech owls. We conclude that owls are not likely to die from secondary poisoning caused by use of endrin-treated forest seed.

Two groups of endrin-killed mice were analyzed to learn how much endrin the hawks and owls were receiving. One group consisted of whole mice, including stomachs full of pine seed. The geometric mean for this group was $26 \mu\text{g}$ per mouse, or 2.7 ppm on a wet weight basis. From the other group the gastrointestinal tract and certain other parts were removed to resemble field-killed mice that had been gutted by a predator. Corresponding geometric means for this group were $7.6 \mu\text{g}$ per mouse, or 0.8 ppm (wet weight). Because hawks and owls may or may not gut their prey, both sets of figures are of value.

Oxychlordane: rate of loss and diagnostic residues in birds.—This metabolite of chlordane is so accumulative and persistent that it will kill birds in long dietary dosage of 1.5 ppm (dry weight). In the field, it is appearing in eggs of many wild birds at levels that sometimes exceed 1 ppm. Study of loss rates revealed, however, that it disappears from living grackles more rapidly than expected. Half was lost from brains after 4 weeks of clean food. Half was lost from bodies after about 10 weeks. At 16 weeks, the end of the study, 66% of the chemical had been lost from brains and 64% from bodies. As these data suggest, little additional chemical was lost from brains between weeks 4 and 16 because the birds were undergoing a loss of body fat that is normal in the spring-to-summer period.

This loss of fat speeded the loss of residues from the body, but maintained the concentration of residues in the blood and hence in the brain.

Residues in brains at death were highly diagnostic. They remained in the same range regardless of species (grackle, redwing, starling), dosage level, or time to death. However, birds that died under stress 1 week after dosage ceased had higher mean residues in brains than any of the others. When oxychlordane was the only chemical fed, residues in brains of birds that died on dosage varied from 5.8 to 16.4 ppm (wet weight). Most residues fell between 8 and 13 ppm. The lethal residues of oxychlordane in brain averaged a little lower than those of dieldrin.

Quail lose DDE rapidly.—Japanese quail were fed 100 ppm DDE in their diet for 10 weeks. The males accumulated only one-fourth to one-half the levels of DDE accumulated by females fed the same diet. Levels of DDE reached a plateau (or equilibrium) in 9 weeks in males and 4 weeks in females, and the DDE was excreted more slowly from males. After the birds were given untreated food, the half-life of DDE was about 42 days in males and 12 days in females. Females eliminated about one half of their daily intake into their eggs.

Species differences shown in toxicity tests.—Comparison of lethal dietary toxicities (LC_{50} 's) of 80 pesticidal compounds tested against young Japanese quail, ring-necked pheasants, and mallards showed the most frequent order of species sensitivity to be quail > pheasant > mallard. This order occurred for 31% of the compounds. The opposite order, mallard > pheasant > quail, occurred for 6% of the compounds. Species responses to organic and inorganic metallic compounds differed. Pheasants were most sensitive to inorganic metallics and mallards were least sensitive; the reverse was true for organometallics, mallards being the most sensitive and pheasants the least.

Age susceptibility of quail to pesticides.—The susceptibility of Japanese quail to parathion decreased with age. Tests of birds at hatching and at 1, 2, and 4 weeks of age showed median lethal concentrations (LC_{50} 's) of parathion to be 2.7 times greater at 4 weeks than at hatching. Susceptibility to dieldrin followed a similar pattern; LC_{50} 's at 4 weeks were 1.4 times those at hatching.

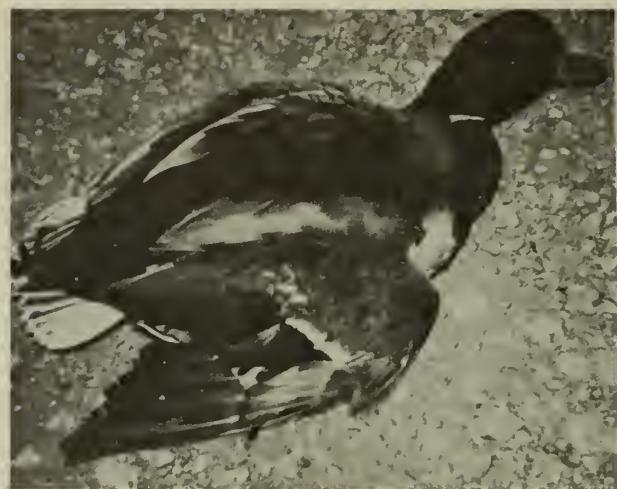
Species and geographic differences in lead burdens in waterfowl.—In nationwide surveys of lead in waterfowl wings, the highest levels were found in mottled ducks and the lowest levels in lesser scaup. Levels in redheads and canvasbacks were intermediate but higher than in mallards, black ducks, and pintails. Wingbones of 4,138 waterfowl contained lead in amounts that ranged from less than 0.5 ppm to 500 ppm. Samples were taken from wings submitted by hunters for the annual harvest surveys in the 1972-73 and 1973-74 hunting seasons.

Lead levels were highest in the Atlantic Flyway States,

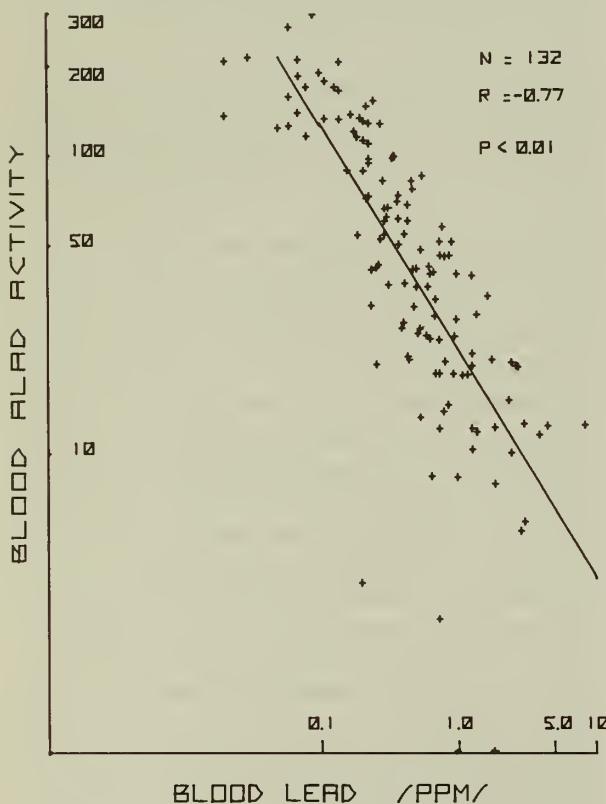
lowest in the Central Flyway, and intermediate in the Mississippi and Pacific Flyways. Black ducks from the Northeast contained lead at levels similar to those in mallards from the same area. Pintails from western States also had amounts similar to those in mallards from the same areas.

Ducks are exposed to lead from sources other than lead shot, and the background levels therefore differ in different areas. The greatly elevated levels found in many of the waterfowl, however, are believed to be the result of ingestion of lead shot, a hypothesis supported by a statistical approach to the interpretation of results.

Canvasbacks have elevated lead levels.—Blood samples from 16 of 95 canvasback ducks trapped and released on Chesapeake Bay in the winter of 1974 showed elevated levels of lead in small samples of blood from the wing. The samples were tested for activity of the delta-aminolevulinic acid dehydrase (ALAD) enzyme, which is specific for lead. The two measurement methods were in consistent agreement; enzyme activity was inhibited in



Mallard duck poisoned by eight no. 6 size lead shot. Drooping of the wings is a characteristic symptom of lead poisoning. (Photo by J. R. Longcore)



Blood enzymes reflect exposure to environmental contaminants. One particular enzyme, delta-aminolevulinic acid, responds specifically to lead. This graph shows the decrease in enzyme activity that occurs in direct proportion to the amount of lead in the blood, as measured by chemical analysis. (Graph by M. T. Findley and M. P. Dieter)

direct proportion to the concentration of lead in the blood.

Effects of lead shot on mallards.—ALAD, an enzyme in the blood involved in the synthesis of hemoglobin, is specifically inhibited by lead. The activity of this enzyme in the blood of mallard ducks was reduced by approximately 90% 1 month after dosage with one No. 4 commercial lead shot. A shot containing lead and iron (47.5% lead) reduced enzyme activity by 50%. Levels of lead in the blood, determined by chemical analysis, were directly proportional to the amount of lead in the shot. ALAD activity was inversely correlated with lead concentration in the blood and therefore is a very sensitive, indirect measure of lead exposure.

Mallard ducks given a single lead shot or a single shot containing lead and iron (47.5% lead) accumulated lead in their bones and transmitted lead to their eggs and eggshells in direct proportion to the amount of lead they received. Lead accumulated in wingbones of females to 10 times the levels in males fed the same dosage, a result apparently related to calcium mobilization during egg laying.

Drake mallards given a single No. 4 lead shot had noticeably elevated levels of lead in wingbones within 24 hours, nearly 20 ppm in 4 days, and more than 100 ppm in 3 weeks. Accumulation of lead in bone paralleled erosion of lead from the shot in the gizzard. More than 5% of the lead pellet had eroded in 24 hours, 30% in 4 days, and more than 60% in 2 weeks. All the shot was eroded in 6 weeks' time. However, 3 months later, lead levels in bone were substantially higher than at 6 weeks. The continued increase evidently resulted from redistribution of body lead from other tissues, since lead levels in livers declined

during the same period.

Effects of chemicals on reproduction of pheasants.—In experimental studies, organic mercury in the diet of ring-necked pheasants severely depressed egg production and markedly increased mortality among females fed diets containing 3.5 ppm of methyl mercury dicyandiamide. In contrast, dietary dosage of phenyl mercuric acetate at 5.0 ppm did not have these effects. Dosages of 40 ppm DDE or of 1 ppm carbofuran produced no adverse reproductive effects when fed in the diet continuously or at 25 ppm for 2-week periods alternating with 2-week periods on untreated diets. None of the four compounds tested produced shell thinning.

Mercury impairs duckling reproduction.—A second generation of mallard ducks fed 0.5 ppm of mercury (as methylmercury dicyandiamide) differed significantly from controls in several ways: they laid a greater percentage of their eggs outside the nest box; they produced 29% fewer ducklings; they ate more feed but did not weigh more; and their offspring gained less weight during the 1st week of life. Eggs contained 0.5-1.1 ppm of mercury. Shell thickness did not differ from controls. In the previous year, the first generation of mallards, which were fed the same mercury dosage, produced 18% more ducklings than controls, but the difference was not statistically significant. Placement of eggs, food consumption, and weight gain were not recorded in the 1st year.

Black ducks fed 3 ppm of methylmercury in their diet for a second breeding season laid fewer eggs than controls, and only 27% of the ducklings survived to 3 weeks, in contrast to 77% of the controls. Results were similar to those during the first season except that hatching success of eggs laid by treated birds was similar to controls in the 2nd year, whereas it was lower in the 1st year. Mercury concentration in the eggs averaged about 5 ppm in both years.

Residues of DDE and PCB's in bats: an agricultural vs. an urban site.—Round Top Mountain, near Hancock, Washington County, Md., is adjacent to extensive apple orchards. Among six little brown bats collected from mine tunnels at Round Top, DDE was the principal residue in carcasses of five, equaling as much as 87 ppm, and PCB's were the principal residues in the sixth bat, amounting to 10 ppm. Among 12 big brown bats collected at Round Top, DDE was the most abundant residue in all 12, amounting to 67 ppm; PCB levels reached 2.4 ppm.

Montpelier Barn, in Laurel, Prince George's County, Md., is surrounded by housing developments, shopping centers, and highways. PCB's were the principal residue in all six little brown bats captured in this barn, reaching 31 ppm; DDE levels reached 8.1 ppm. Guano contained 0.32 ppm DDE and 0.96 ppm PCB's. Among 16 big brown bats, DDE was the most abundant residue in 10,

among which 1 bat contained 10 ppm. However, PCB's exceeded DDE in four bats (two bats had equal amounts of DDE and PCB's) among which one contained 13 ppm.

Organochlorines in eggs of insectivorous birds.—Progress in the evaluation of the levels and effects of organochlorines on insectivorous birds included analysis of 87 eggs of five species (roadrunner, robin, loggerhead shrike, mockingbird, and purple martin) collected in 1973. The limit of detection was 0.1 ppm. Eggs of roadrunners (from Arizona, near Tucson) were least contaminated. The only chemical detected was DDE, and this was in only two of seven eggs from seven different clutches. Loggerhead shrike eggs had the highest residues, one containing 65.7 ppm of DDE, 6.15 ppm DDT, 2.96 ppm of mirex, and detectable amounts of seven other compounds. DDE ranged from 0.15 ppm to 6.12 ppm in the other 14 eggs.

DDT was present at levels of 0.1 ppm or higher in 27 of 44 robin eggs and 10 of 15 shrike eggs, a greater frequency than would have been expected in view of the relatively rapid change of DDT to DDE in the environment and the reduced use of DDT. DDT was not found in eggs of the roadrunner, mockingbird, or purple martin, although DDE occurred in at least some samples of all species.

PCB's also were prevalent, occurring in 38 of 44 robin eggs, all of 15 shrike eggs, all of 13 mockingbird eggs, and 4 of 7 purple martin eggs. PCB's have been widely reported in birds feeding in aquatic sites, which receive a variety of wastes. The source of PCB's in these terrestrial species is not known.



Immature black-legged kittiwake. Eggs of Alaskan seabirds from three of four localities contained small amounts of organochlorine residues. (Photos by James Bartonek)

Organochlorine residues in seabird eggs.—As part of a joint effort of the Northern Prairie and Patuxent Wildlife Research Centers to assess status and trends of Alaskan seabirds in relation to environmental disturbance, 45 eggs of five species of Alaskan seabirds were collected in 1973. Analysis verified low residues of organochlorines in samples from three of four localities. Species sampled included the double-crested cormorant, glaucous-winged gull, common murre, black-legged kittiwake, and tufted puffin. DDE was present in eggs of all species from all localities, but amounts did not exceed 0.7 ppm except in the eggs of glaucous-winged gulls from Bogoslof Island that contained up to 11.2 ppm. Maximum levels of other chemicals also were present in these gull eggs, including 6.3 ppm of PCB's, 0.6 ppm of dieldrin, and 0.04 ppm of mirex. Dieldrin, oxychlordane, HCB, and PCB's were present in all species from all localities; DDT, DDD, heptachlor epoxide, mirex, alpha chlordane, and beta nonachlor occurred less frequently. Additional samples were collected in 1974. The remote location of Bogoslof Island near the tip of the island chain provides no clue to the source of these chemicals.

Chemical pollutants in the mid-Atlantic.—Residue levels were analyzed in seabirds collected off the coast of southern Iceland to learn more about the gradient of pollution across the Atlantic Ocean. Coastal-dwelling species, represented by gulls and jaegers, had mean levels of 1.7-2.7 ppm of PCB's in their breast muscles. Oceanic species like auks, puffins, fulmars, and shearwaters averaged somewhat lower, 0.4-2.3 ppm. These levels were about 3-12 times higher than those of DDE, the environmental degradation product of DDT.

This preliminary evidence suggests that pollution levels off the coast of southern Iceland are fairly similar to those reported by British workers for the coasts of Scotland and considerably lower than those published by Canadian investigators for the eastern coast of North America.

Effects of DDT in Lake Michigan birds.—Studies have shown an overall decrease in the mean weight (and hence thickness) of eggshells of herring gulls in the western Great Lakes area, the means having dropped 2% in 1947-48, 5% in 1951-58, 8% in 1960-69, and 8% in 1970-74. The maximum eggshell changes occurred in 1964-65. A recent possible increase in shell weight and thickness since the banning of DDT is, to some extent, masked by the variability of the data. Shell thinning in 1974 was considerably less than it was in 1964-65.

The productivity of herring gull colonies in Green Bay, Wis., was found to be 0.36 young per pair in 1974 on Little Sister Island where storms damaged some peripheral nests, but embryonic mortality occurred in at least 35% of the surviving nests. The net productivity per pair this year is similar to the record low reported for this species in the

same area in 1964. Productivity of the gulls on nearby Big Sister Island was much better, although 42% of the nests contained one or more eggs with cracks.

In recent years the numbers of herring gulls in these colonies have declined greatly. While part of these decreases may be explained by a parallel increase in the water level of Lake Michigan, it seems probable that much of the change in the numbers of nesting gulls in the Green Bay area is due to the very poor reproductive success recorded in the mid-1960's when the effects of pollution on these birds were quite conspicuous.

Chemical residues in screech owls.—Chemical residues were low, eggshell thickness was normal, and nesting success was good in a wild population of screech owls in northwestern Ohio, in 1973. The contents of one egg from each of 21 clutches were collected at the beginning of the nesting season and unhatched eggs were collected after incubation. DDE was present in all eggs, averaging 1.3 ppm (range, 0.33-2.8 ppm); PCB's, also present in all eggs, averaged 1.32 ppm (range, 0.26-3.4 ppm). Dieldrin was found in eight clutches (range, 0.10-0.24 ppm). DDD, DDT, heptachlor epoxide, mirex, oxychlordane, *cis*-chlordane, and hexachlorobenzene were each found in at least one clutch but in not more than three clutches. Residue levels of all of these chemicals were below 0.23 ppm. There appeared to be no association between residues and hatching failures. Shell thickness of eggs in 1973 was not significantly different from that of eggs collected in Ohio prior to 1935.

Pollutants in Maryland barn owls.—Shells from eggs of 28 clutches sampled in 1972 and 1973 were about 5.5% thinner than those of pre-1946 eggs from museums. Fifty eggs from 20 clutches were analyzed chemically. Average DDE residues in a clutch ranged from 0.28 to 15.45 ppm; PCB's ranged from 0.16 to 7.00 ppm. Dieldrin was not detected in six clutches, but in 14 clutches residues ranged from a trace to 2.43 ppm. Other chemicals detected included DDT, DDD, mirex, oxychlordane, *cis*-chlordane, and toxaphene. Captive barn owls reproduced normally with DDE and PCB residues of 0.1 to 1.0 ppm in the eggs, but the level at which adverse effects may occur has not been ascertained.

Pesticide levels in limpkin eggs.—A total of 14 eggs of the limpkin, collected near Lake Okeechobee, Fla., in 1973 and 1974, were analyzed for PCB's, DDE, DDD, DDT, dieldrin, mirex, chlordane metabolites, heptachlor epoxide, and hexachlorobenzene. DDE was the only compound detected and it was present in only 4 of the 14 eggs analyzed. One of the four eggs contained 5.6 ppm (wet weight) but each of the other three contained less than 0.25 ppm. The level of detection was 0.1 ppm.

Shell thickness and residues in brown pelican eggs.—In 1969 and 1970, a survey of shell thickness of



The shells of screech owl eggs in northwestern Ohio were not significantly thinner than those laid before 1935, although all contained DDE averaging 1.3 ppm. Captive screech owls fed 3 ppm of DDE laid thin-shelled eggs at Patuxent. (Photo by J. R. Longcore)

brown pelican eggs in Atlantic and Gulf Coast colonies showed that shells had thinned conspicuously in the South Carolina colonies since the 1940's, a period when the pelican population declined from more than 5,000 pairs to 1,250 pairs. The decrease in thickness approached 17%. In contrast, shells from pelican nests along the Atlantic coast of Florida were 9% thinner and those from the Gulf Coast were 7.5% thinner than in previous years. Five years later, in 1974, shell thickness remained the same as in 1969 in both the South Carolina colonies and those on the Atlantic coast of Florida. Average measurements suggested a possible improvement in Gulf Coast colonies, which was not validated by statistical tests.

Residues of DDE in eggs of brown pelicans nesting in South Carolina have declined from an average of 5.45 ppm in 1969 to 2.09 ppm in 1973, and residues of dieldrin have dropped from 1.16 ppm to 0.45 ppm in the same period. Levels of PCB's have not changed detectably. Improvements in reproductive success appeared in the South Carolina colonies in 1973. In 1974, reproductive success varied considerably in the different South Carolina colonies, from excellent to poor.

No downy young were produced in brown pelican nests in which egg residues exceeded 3.7 ppm of DDE or 0.94 ppm of dieldrin. In nests where some young were produced, reproductive success was progressively poorer as eggs contained higher residues.

Pesticides in estuarine birds in South Carolina.—Comparisons of shell thickness of eggs laid in 1974 with those laid before the 1940's showed no significant changes for royal terns, black skimmers, gull-billed terns, Sandwich terns, and white ibises. Shell thickness of least tern eggs, however, was 6.6% lower than that of museum eggs. Several of these species reproduced poorly in 1974, including skimmers, gull-billed terns, and least terns. Many nests were flooded with water, but this was not the entire cause of the poor success, which remains incompletely diagnosed.

Equipment modifications speed and improve residue analysis.—A single chemical computing integrator was evaluated and adopted for completely automating analysis of chemical residues by gas chromatography. The computer integrator measures retention times and peak areas of chemicals and from this information computes the



Brown pelicans at Cape Romain National Wildlife Refuge. Chemical residues in the eggs have declined conspicuously since 1969. High water may take a heavy toll of nests in some years. (Photo by L. J. Blus)

amount of each component in the sample. The complete system will analyze, unattended, as many as 36 samples.

The LKB gas chromatograph-mass spectrometer (a specific instrument) was modified for mass fragmentography or single ion detection. This modification increased the lower limit of detection at least tenfold and made it possible to confirm residues at a level of 0.005 ppm.

Southeastern Fish Cultural Laboratory

Persistence and bioaccumulation of organochlorine contaminants.—Trace contaminants that may adversely affect growth, reproduction, and survival by contact exposure can accumulate in fish from natural forage or artificial food. To help evaluate endrin uptake from this route of entry and subsequent release rates, biologists at the Southeastern Fish Cultural Laboratory dosed channel catfish fingerlings with an endrin-contaminated diet (2.5 $\mu\text{g/g}$ dry weight) for 147 days. The fish accumulated up to 0.49 μg endrin per gram of fish (whole fish basis). In fish

parts the concentrations (μg endrin per gram) were: liver, 0.2; gastrointestinal tract, 1.1; kidney, 1.5; and carcass remains, 0.6. After 44 days on a contaminant-free diet, endrin had been decreased to undetectable levels in the liver and kidney, and to 0.05, 0.03, and 0.04 $\mu\text{g/g}$ in the gastrointestinal tract, whole body, and carcass remains, respectively. An average half-life of 12 days was estimated for whole fish samples. If the source of contamination is removed, a reasonably rapid reduction of endrin residues to levels that meet Federal standards for food fish apparently can be expected.

Persistence of mirex (a chemical used in the control of fire ants) in pond sediments, and subsequent accumulation by channel catfish, was recently observed at the Southeastern Fish Cultural Laboratory. Residues as great as 1.1 $\mu\text{g/g}$ were still evident in pond sediments 9 years after applications of 0.1 to 1 mg mirex per liter of water. A biologic half-life of at least 2.5 years was estimated from these analyses. Channel catfish maintained in these ponds for 300 days accumulated up to 1.4 μg mirex per gram (whole fish basis). Although the use of mirex in the fire



White ibis in South Carolina. The value of colonial-nesting wading birds as indicators of the kinds and amounts of environmental contaminants has been substantiated. Their value as indicators of other environmental factors is being investigated. (Photo by L. J. Blus)

ant eradication program will probably be discontinued, residues can be expected to persist for years and retain a potential for bioaccumulation. Mirex may tend to accumulate in bottom sediments and then be taken up by bottom-feeding organisms.

Reproduction in fish exposed to endrin and toxaphene.—Endrin and toxaphene are applied extensively to agricultural areas of the Southeast, and the residues are often found in dead or moribund fish. Adverse effects on reproduction were indicated by a study in which ponds were contaminated at rates comparable to those used for spraying cotton-farming areas of the Southeast. Male goldfish exposed over one growing season to 11 applications totalling 0.5 to 4.0 μg toxaphene per liter and 0.05 to 0.2 μg endrin per liter, either alone or in combination, accumulated up to 0.06 $\mu\text{g/g}$ of endrin, 1.3 $\mu\text{g/g}$ of toxaphene, and 0.04 + 1.2 $\mu\text{g/g}$ of endrin + toxaphene. The respective values for females were roughly similar: 0.07, 0.5, and 0.03 + 0.8 $\mu\text{g/g}$. Successful spawns resulted in the following spring from 67% of the controls, and from 50, 17, and 50% of the fish exposed to toxaphene, endrin, and endrin + toxaphene, respectively.

Washington, D.C., Office

Mercury residues in wild ducks.—Samples of breast muscle from 327 ducks collected during October 1970-March 1971 in the conterminous States were analyzed for total mercury by flameless atomic absorption spectrometry. Mercury levels for the entire collection ranged from <0.01 to 3.91 ppm, with a median of 0.10 ppm (all readings based on wet weights). Twenty-four ducks had levels equalling or exceeding the Food and Drug Administration (FDA) 0.5 ppm guideline for fish and shellfish. Dabbling ducks (mostly vegetarian in fall, winter, and spring) in most collections had lower levels than diving and sea ducks. Levels generally were higher in ducks collected in areas where environmental mercury levels were known to be high than in nonsuspect areas. Despite the mobility of the ducks, levels seemed more closely linked to local environmental contamination than to factors operating throughout large geographic areas.

COASTAL AND ANADROMOUS FISH

Atlantic Salmon Investigations

Studies to restore the Atlantic salmon fishery.—The Atlantic salmon, considered an endangered species less than a decade ago, made repeated headlines in New England in 1974-75. Adults returned from the sea in record numbers to streams in Maine, and in smaller numbers to

the Connecticut River. The marked increase in Atlantic salmon numbers is largely attributable to research in nutrition, disease control, cultural methods, stocking, and migrations.

Biologists of the Atlantic Salmon Investigations are continuing studies on the suitability of rivers for salmon restoration. One such study, concerning possible restora-

tion in the international waters of the St. Croix River, is being conducted in cooperation with the Fisheries and Marine Service of Canada and the North American Salmon Research Center.

Young salmon migrating to the sea face many deadly hazards, such as dams, diversions, turbines, pollution, and predatory fish, birds, and mammals. The routes and rates of migration by the young salmon from the rivers, through estuaries, and into the sea must be defined before hatchery-reared salmon can be stocked to best advantage and obstacles to their safe movement corrected. Under a U.S. Fish and Wildlife Service contract, researchers of the Migratory Fish Research Institute at the University of Maine have fitted young salmon with tiny ultrasonic transmitters, released them into the Penobscot River, and tracked them by means of hydrophones down the river and into Penobscot Bay. Movements of the fish were slight until the river warmed to 45°F and higher in May. Thereafter for 2 weeks, the tagged salmon moved rapidly downstream, through the freshwater-saltwater interface, and into the sea, traveling night and day within 6 feet of the water surface. In a separate, concurrent study, Service biologists tracked young salmon through the freshwater portion of their migration, past dams and other obstacles in the same river, by inserting miniaturized radio transmitters into the fish stomachs and monitoring the radio signals with shore-based receivers.

In one of two Service-sponsored studies at the University of Maine, biologists have learned that the elevation of an enzyme in the gills of young salmon, indicating the fish's readiness to migrate to sea, can be applied to hatchery-reared salmon to pinpoint the most appropriate time for stocking. In the second study, a technique has been developed for the identification of genetically different stocks of Atlantic salmon in North American rivers. Salmon stocks in five Maine rivers have been characterized, and the investigators have extended observations into Canada at the request of the Canadian Fisheries and Marine Service.

Eastern Fish Disease Laboratory

Enteric redmouth disease (ERM).—This disease, formerly termed Hagerman redmouth disease, is a systemic bacterial infection which affects trout and salmon and has typically been found in the intermountain West. Recently, however, ERM was found in Canada and in the midwestern and southwestern United States. Current interest in expanding the propagation of Atlantic salmon made it imperative that salmon be tested for susceptibility to ERM. In that testing, ERM was compared with furunculosis, a disease known for its virulence in Atlantic

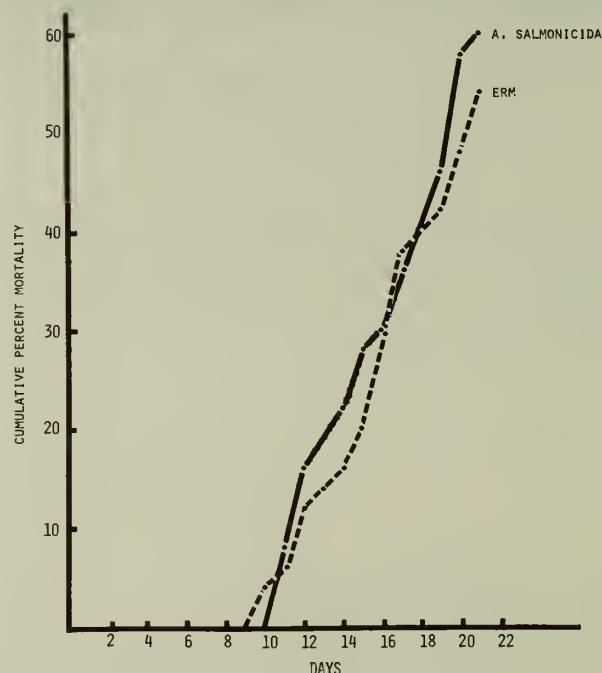
salmon.

Two kinds of tests were carried out with fingerling salmon 5-6 cm long. In the first, fish were injected with either ERM or furunculosis and held for observation at 13°C. In the second, salmon were merely exposed by adding cultures to the water or by holding the fish in raceways downstream from infected trout.

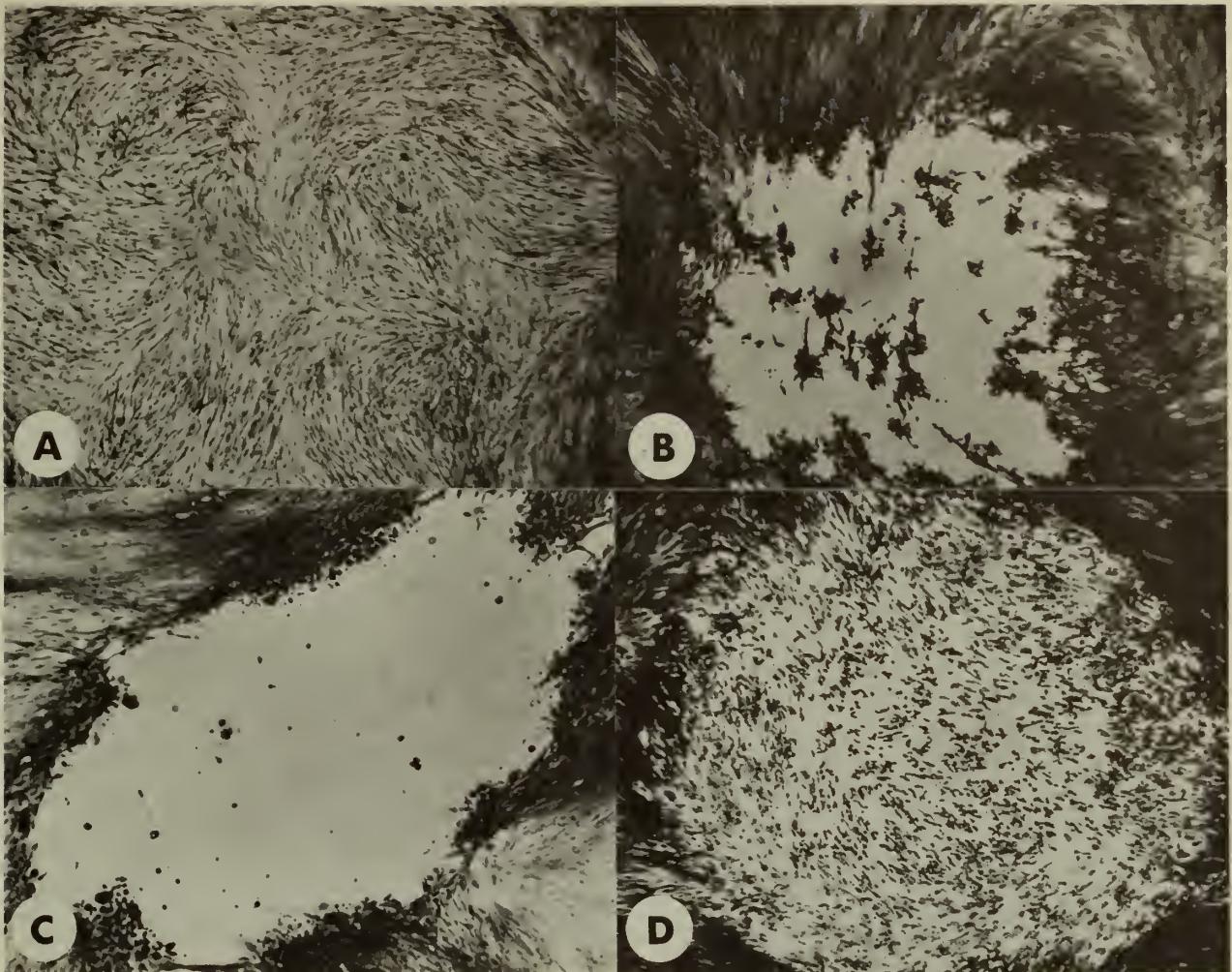
Injection of salmon with two strains of either bacterium resulted in 100% mortality within 4 days. Fish merely exposed to the organisms also sustained high losses; 50% of the fish exposed to ERM and 70% of those exposed to furunculosis died within 14 days. In addition to the comparable mortalities, the two pathogens produced similar patterns of death. These studies clearly show that Atlantic salmon are highly susceptible to ERM.

The Eastern Fish Disease Laboratory prepared a Fish Disease Leaflet on ERM, and revised Fish Disease Leaflets on kidney disease, furunculosis, and hemorrhagic septicemia, to enable field personnel to keep abreast of research developments.

Infectious hematopoietic necrosis (IHN).—This viral disease affects young rainbow trout and two species of Pacific salmon. For years, the disease was found only in the Pacific Northwest, but recently it spread eastward—apparently with shipments of contaminated eggs



Mortality among Atlantic salmon exposed for 21 days in water containing either the bacterium causing furunculosis (*Aeromonas salmonicida*) or the bacterium causing enteric redmouth disease (ERM).



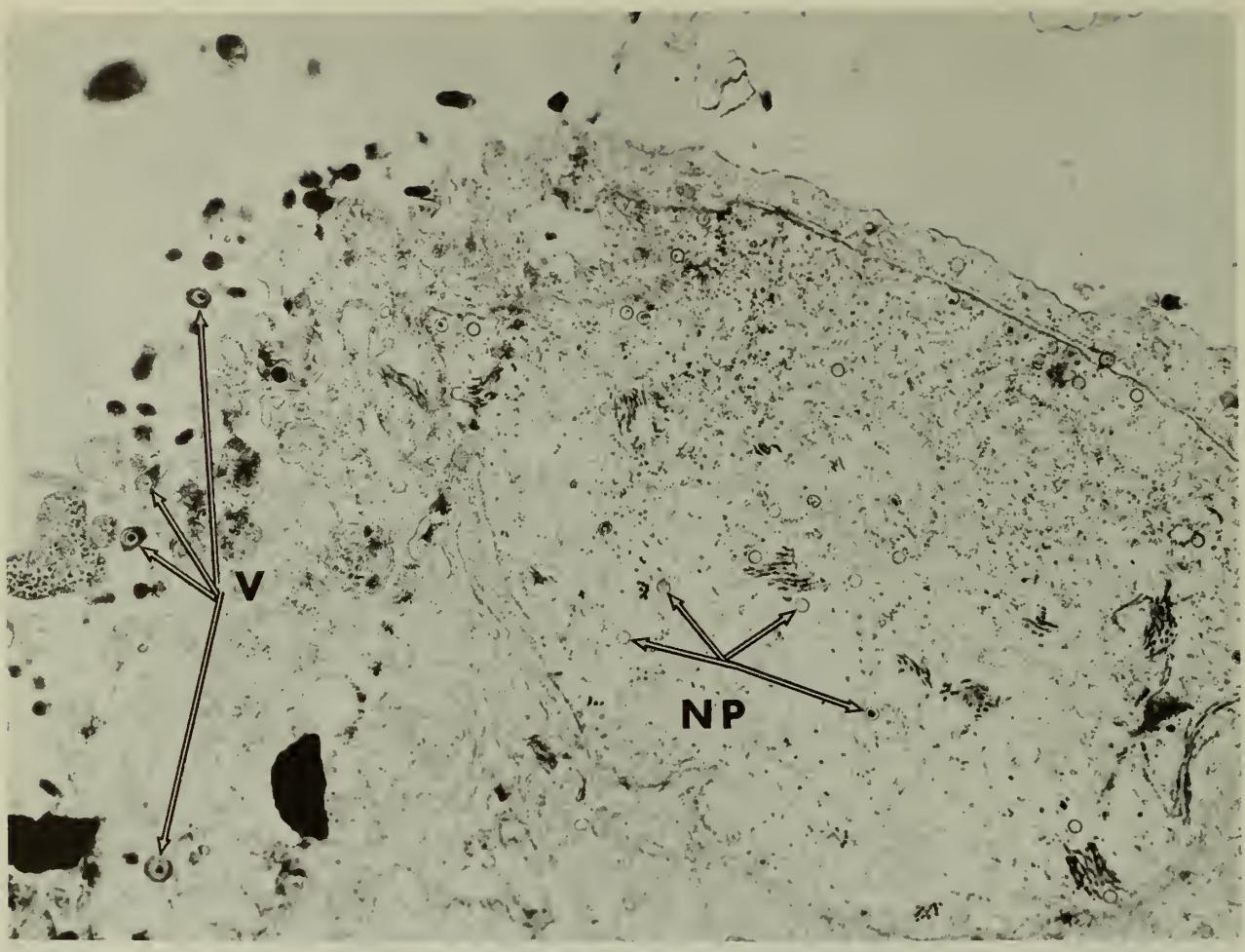
Trout and salmon viruses produce characteristic changes in cell culture sheets. These are valuable in identifying viruses and in detecting the presence of two or more in the same specimen. The culture sheets shown represent: (A) infectious pancreatic necrosis, (B) infectious hematopoietic necrosis, (C) rainbow trout herpesvirus, and (D) viral hemorrhagic septicemia. (Photos by K. Wolf)

or infected fish. Biologists of the Eastern Fish Disease Laboratory attempted to infect Atlantic salmon with the virus because salmon require low water temperatures (which favor outbreaks of IHN), and because the susceptibility of the species is not known. Fingerling Atlantic salmon were injected with IHN virus, and fingerling rainbow trout were similarly treated to serve as known susceptible hosts. The salmon and trout proved to be about equally vulnerable to the disease—a finding that demonstrates the need for vigilance in preventing exposure of Atlantic salmon to IHN.

New herpesvirus of rainbow trout.—During the past 4 years, several hatchery populations of rainbow trout brood stock in the Pacific Northwest sustained postspawning mortality of 30-50%. Presumptive evidence of a virus was reported by one laboratory, but could not be con-

firmed at another. In spring 1975, the virus was confirmed in inoculated cell cultures sent to the Eastern Fish Disease Laboratory.

The Laboratory began research to describe the agent and determine its effects on Atlantic salmon and brook, brown, and rainbow trout. Biophysical properties indicated that the virus is a previously unrecognized pathogen, and electron microscopy showed it to be a member of the herpesvirus group. The new herpesvirus produced 100% mortality in rainbow trout. Histopathological examination showed a previously unknown pattern of disease in liver and blood-forming tissues. In contrast to other serious viral diseases of fishes—especially the catfish herpesvirus, which has a 3- to 5-day incubation period—the rainbow trout herpesvirus requires more than a month to kill its host.



Electron micrograph of a cell infected with the newly isolated rainbow trout herpesvirus. "NP" arrows point to early stages of virus particles that are produced in the cell's nucleus. "V" arrows indicate mature infectious particles which have been released and are outside the cell. (Photo by R.W. Darlington, Univ. Kentucky)

New viruses in American eels.—Some eels in Europe bear tumors, predominantly on the mouth, head, and anterior body. A virus, designated EV-1, has been isolated from eels with tumors, but cause and effect have not been proved. Dr. T. Nagabayashi, a visiting Japanese scientist at the Eastern Fish Disease Laboratory, studied the characteristics of EV-1 and showed it to be a distinct RNA virus. American eels measuring 10-18 inches were obtained for experimental inoculations, but a virological examination revealed that they already harbored two viruses—EV-1 and a new agent—and therefore could not be used in the study. Series of 3- to 5-inch elvers were then injected with one or the other eel virus, and placed under observation. The results should have significance in the development of eel husbandry in America, and will also be important because many elvers and adult eels are exported to Europe and Japan.

Fish Control Laboratory

Therapeuticants for fish.—Malachite green is commonly used as a fungicide and parasiticide in fisheries. Despite its long history of use, few controlled laboratory studies of its effects have been conducted. In one experiment, coho salmon were exposed to 0.1 mg/l of malachite green for 28 days in a flow-through system at 12° C. Samples of 10 fish each, taken after 1, 2, 4, 7, 14, and 28 days of exposure, were anesthetized in a 200-mg/l solution of Finquel, and blood samples were obtained. Analyses for hemoglobin, hematocrit, glucose, total protein, sodium, potassium, calcium, and magnesium showed no dramatic shifts in the blood chemistries of the treated fish.

Eyed eggs of coho salmon were divided into two groups; one group was treated with 0.1 mg/l of malachite green continuously until they hatched and the other was



Common eel bearing a large tumor on its mouth parts. Biologists have isolated viruses from these animals to determine if the viruses caused the tumors. These studies with experimental animals have a direct relation to human cancer research. (Eastern Fish Disease Laboratory photo)

incubated without exposure to malachite green. After the young fish had reached a weight of 0.6 g, their responses to selected chemicals were measured. The responses of treated and untreated fish to Bayer 73 and formalin were similar, but the treated fish were about twice as resistant to malachite green and 3 times more resistant to Dylox.

Registration-related activities.—Biologists of the Fish Control Laboratory continued their efforts toward the registration of fishery chemicals. Petitions for exemption of tolerance were submitted to the Environmental Protection Agency (EPA) on formalin, lime, and sodium chloride. The use pattern for formalin was ruled to be that of a therapeutic rather than of a pesticide, and EPA sent the petition to the Food and Drug Administration (FDA) where action is pending. Lime and sodium chloride were declared "generally regarded as safe" (GRAS). New animal drug applications (NADA) were filed with FDA on quinaldine sulfate and its mixture with MS-222.

Research on lampricides, piscicides, collecting aids, malachite green, and $KMnO_4$ continued to the extent that funds and manpower permitted. Work on TFM and the Bayluscide:TFM mixture, which has mainly been done through outside contracts, is on schedule.

The list of currently approved fishery chemicals now includes Terramycin, sulfamerazine, Masoten, endothall, simazine, copper sulfate, lime, and salt.

Literature reviews.—The literature review project on 20 priority fishery compounds undertaken in October 1973 was completed in May. In August, literature reviews



Research on the effects of fishery chemicals includes testing the eggs of trout and salmon in continuous-flow toxicity tests. (Photo by Leif Marking)

on the following 18 compounds were submitted to the National Technical Information Service (U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Va. 22151) for sale to the public: antimycin, Bayluscide, Bayluscide:TFM, Betadine, calcium hypochlorite, copper sulfate, diuron, Dylox, endothall, formalin, lime, malachite green, malachite green:formalin, potassium permanganate, rotenone, simazine, Squoxin, and 2,4-D.

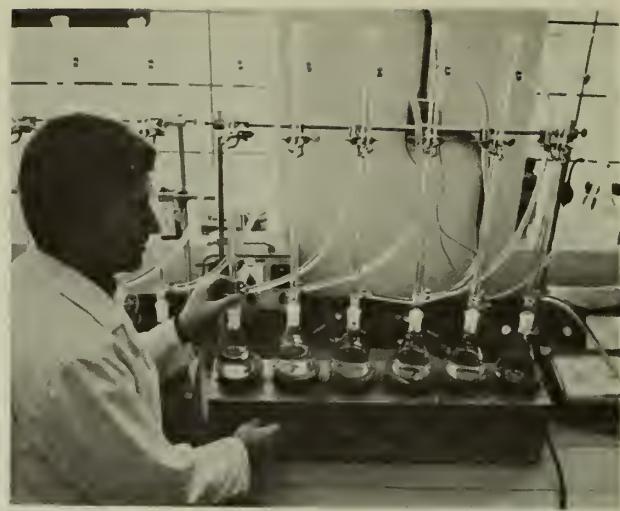
Fish Farming Experimental Station

Parasites of striped bass.—Interest by sportsmen and fishery management personnel in establishing striped bass in large impoundments and river systems continues to grow. This species has been established in 16 States and is successfully cultured in several others. However, several diseases have been observed in cultured fish, and some diseases have been diagnosed in individual fish long after they have been stocked. The known disease agents include myxobacteria, *Branchiomyces*, *Posthodiplastomum minimum*, and *Goezia*.

Often it is desirable to determine the extent of disease problems in fish before expensive and time-consuming research is begun to eliminate what could be only a minor problem. The Fish Farming Experimental Station is contacting fish hatcheries culturing striped bass to determine the nature and extent of disease problems; appropriate research will be initiated later if needed. In addition, a literature review of the parasites and diseases of striped bass has been prepared.

Southeastern Fish Cultural Laboratory

Cryopreservation of striped bass sperm.—In the collection of striped bass eggs for incubation, a common problem is a shortage of sperm late in the spawning season when ripe females are still available. Males migrate up coastal rivers before the females and are difficult to collect during the latter part of the spawning run. If sperm could be preserved, production of fertile eggs might be increased. Preservation by freezing requires a diluent with a balanced salt composition to ensure the retention of sperm motility. As a first step in the development of a suitable artificial diluent, seminal fluid from ripe males was analyzed for osmolality and ion quality. Osmolality averaged 350 ± 2.0 m Osm/l and potassium, sodium, and chloride levels averaged 42 ± 0.8 , 116 ± 1.7 , and 120 ± 7.0 mEq/l, respectively. Artificial diluents, with these electrolyte concentrations and additions of lecithin and dimethylsulfoxide, protected sperm morphology after the sperm had been immersed in liquid N₂ vapor and later rapidly thawed; however, motility had been lost.



The determination of environmental effects of contaminants frequently involves complex water chemistry procedures such as testing for chemical oxygen demand. (Photo by Leif Marking)

Nutrition and intensive culture of striped bass.—Intensive culture of striped bass fry and fingerlings in tanks can alleviate many problems inherent in pond production, such as fluctuations in temperature, pH, dissolved oxygen, and forage. Food of adequate quality and quantity is a critical need of postlarval striped bass, and attempts to rear fry with artificial diets have usually failed. To develop tank culture procedures offering improvements over pond production, biologists at the Southeast Fish Cultural Laboratory stocked aquaria with 6-day-old striped bass fry and fed the fish laboratory-reared daphnid and cyclopoid zooplankton. During the critical early stages, the fry accepted an artificial microencapsulated (50μ) diet as a gradual replacement for the cultured forage. This test demonstrated that tank culture is a feasible alternative to the less predictable pond culture.

Growth and survival of striped bass fingerlings were compared among groups receiving 38-54.5% protein (casein) and 0-6% salmon oil supplementing 6% corn oil in diets fed at the rate of 2.5 and 5.0% (dry basis) of body weight per day. Variance analysis demonstrated that diets having more than 38% protein (casein quality) offered no advantage in growth or survival. Salmon oil supplements of 3 and 6% increased growth 61 and 107%, respectively. Growth rates at the two feeding rates tested were not significantly different. The addition of linolenic acid apparently improved diet quality. Tests of feeding rates of 1, 2, and 3% of body weight, with diets having 38 or 54.5% protein (both with 3% salmon oil and 6% corn oil), revealed a clear break in limiting amounts between the 1 and 2% feeding rates for both diets; no growth difference was noted between the 2 and 3% feeding rates with either

formulation. These results may be used to formulate practical rations for striped bass.

In other studies of striped bass culture, growth rates were 19% greater at 29°C than at 22°C. Striped bass held in circular tanks at 1, 2, and 3 fingerlings per 4 gallons of water yielded weight gains of 1,033, 909, and 857% and conversion efficiencies of 1.73, 1.76, and 1.77, respectively. This information may help culturists develop standard culture procedures having predictable results.

Tunison Laboratory of Fish Nutrition

Environmental requirements of salmonids.—The direct absorption of dissolved calcium from water by fingerling rainbow and steelhead trout and the influence of water chemistry on this absorption and on the utilization of dietary calcium was investigated at the Laboratory. A label for both the food and water was supplied by ^{45}Ca -calcium. Increased salinity (provided by dissolved potassium and sodium) caused stress and mortality, but it also induced a significantly faster rate of food digestion without incurring an extensive loss of calcium nutrition. A high calcium level in the feed reduced toxic effects of increased salinity, as did added water hardness provided by strontium and magnesium. Food and water minerals interacted to improve the metabolism and survival of cultured salmonids.

A closed-culture system was required for acclimation of presmolt Atlantic salmon to experimentally increased salinities. Nonbiodegradable colored matabolic products accumulated as a result of 100% water reuse. An ozone-generated froth provided a means of removing most of these residual wastes. A level of 0.05 ppm ozone permitted the culture of salmon without water change for a 7-month experimental period, without harm to the fish. The use of ozone-froth will be applied to practical salmonid culture in closed-culture systems.

Correlation of Na-K gill ATPase activity with migratory behavior in Atlantic salmon.—In an earlier study, periodic samplings of the gills of Atlantic salmon parr and smolts reared indoors at 9°C showed that maximum gill ATPase activity was reached in mid-May, the time when salmon normally migrate from a freshwater to a saltwater environment. In a confirmatory experiment, biologists of the Tunison Laboratory monitored the gill ATPase activity of Atlantic salmon held and sampled under outside hatchery conditions preceding the release of smolts at Craig Brook National Fish Hatchery, East Orland, Maine. A single sampling of gills of wild smolts in nearby streams and of smolts released into a streamside pond was also made.

Results of this study, in agreement with those of the earlier study, showed that gill ATPase activity was high-

est near the time the salmon were released from the hatchery ponds. The gills of fish held in the smolt-release pond showed a significantly reduced enzyme activity compared with those sampled in the streams and hatchery ponds at the same time. High water temperature in the release pond may have caused this reduced activity.

These findings support the potential usefulness of fluctuations in gill ATPase activity for prediction of the optimum time for release of Atlantic salmon smolts from the hatchery.

Practical diets for Atlantic salmon.—Because most diets fed hatchery reared Atlantic salmon are of foreign origin and very expensive, efforts have been made to formulate diets with practical, commercially available ingredients indigenous to this country. Formulations, processing technology, and nutritional suitability have been established for diets to be used during the various phases of hatchery life. Inasmuch as the diets are much more economical than those of foreign origin, they are already being field tested.

Mineral and amino acid supplementation with plant protein.—Several nutritional experiments were conducted with fingerling Atlantic salmon to determine the influence of supplementing diets containing commercially dehulled solvent extracted soybean meal as a major source of protein. The supplements included the trace element manganese and five essential amino acids (leucine, valine, threonine, methionine, and lysine). Various trace elements are known to be essential in diets of terrestrial animals to prevent specific nutritional deficiency diseases, as well as to permit maximum utilization of the various essential amino acids that are the vital components of protein.

These studies with salmon showed that supplements of manganese and various amino acids are essential for maximum growth and optimum feed conversion. Furthermore, the quantitative requirement for dietary manganese is apparently influenced by age of the fish or manganese content of the water, or both. The experiments with amino acids showed that complex balances of several specific amino acids improved the nutritional value of the protein in soybean meal to the extent that it approached that of the expensive protein source (refined fish meal) currently used. In summary, these experiments demonstrated a high potential for the use of economical plant proteins as substitutes for fish protein in diets fed to Atlantic salmon or other salmonid fishes.

Utilization of vitamin A, beta-carotene, and vitamin D₃ at two water temperatures.—Studies were conducted at two water temperatures (9° and 12.4°C) to determine the utilization of vitamin A palmitate, beta-carotene, and vitamin D₃ as measured by growth and survival of Atlantic salmon. Fish not fed supplemental vitamin A developed

dermal depigmentation, peritoneal edema, and a pronounced protrusion of the eyes; fluid accumulated within the anterior chamber of the eyes, the lens was displaced, and the retina was degenerated. Cataracts were not observed.

The feeding of 10,000 IU vitamin A palmitate per kilogram of feed promoted a growth increase of 51% at 9°C and 175% at 12.4°C. A similar level of vitamin A as dietary beta-carotene produced increases in growth of 26 and 41%, compared with the growth of fish fed a vitamin A-deficient diet. Vitamin D₃ promoted additional growth when it was fed with vitamin A, but not when it was fed without vitamin A.

Optimum levels of fat in Atlantic salmon diets.—It has been reported that relatively high levels of dietary fat (16%) improve the health of Atlantic salmon. Further knowledge of the optimum level of dietary fat is needed. In tests of diets prepared from herring oil, soybean oil, water, vitamins, and minerals (no carbohydrate), the weight gain was greatest in salmon fed the most fat and the least protein.

Western Fish Disease Laboratory

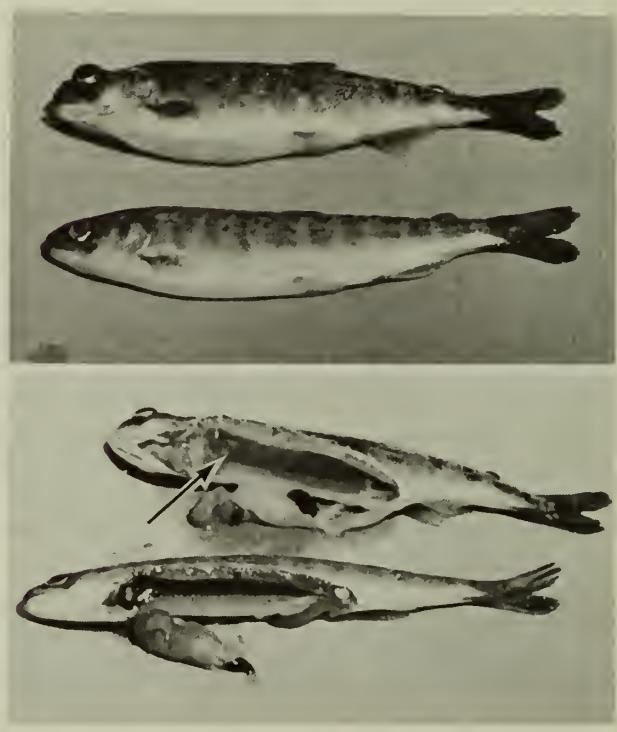
Virus disease of sockeye salmon.—Serious depletion of sockeye salmon runs in Alaska in recent years has prompted that State to evaluate various rehabilitation projects to increase these runs. Some of these projects involve rearing fish for short periods before they are released into natural waters. At one test site a serious mortality (about 99% of 100,000 fish) was attributed to a virus disease, infectious hematopoietic necrosis (IHN). Fishery managers considered it important to determine the distribution of this virus in sockeye salmon stocks before additional or expanded projects were attempted. Therefore a study of virus diseases of sockeye salmon was initiated by the Western Fish Disease Laboratory in cooperation with the Alaska Department of Fish and Game.

During summer 1974, 16 spawning stocks of sockeye salmon were tested for presence of IHN virus carriers. The virus was found in all stocks tested, which included fish from Bristol Bay, Kodiak Island, Cook Inlet, and the Gulf of Alaska. An average of 44% (range, 7-94%) of the samples of females and 13% (range, 0-48%) of the males were carriers of the virus. It is apparent that this viral disease could be an important factor in reducing the size of salmon runs. Work is continuing to develop methods of controlling the disease.

Possibilities of developing disease-resistant sockeye salmon.—One possible method of reducing the impact of disease is to develop disease-resistant fish. Sockeye salmon from streams in Washington State were spawned and

a portion of the progeny from each female was challenged with IHN virus for 5 months. Susceptibility to disease of the progeny from different females differed significantly, and this difference was evident throughout the test period. Possibly the resistance is inheritable and this characteristic can be used to develop resistant stocks of fish.

Undiagnosed disease of chinook salmon.—Chinook salmon fingerlings showing leukemia-like lesions were observed in a state hatchery. The clinical signs exhibited by these fish—distended abdomen, fluid in the abdominal cavity, popeye, and swollen kidney—were those typically associated with cornynebacteria (bacterial kidney) disease. Histological analyses indicated extensive increases in the density of white blood cells in many tissues. Bacteriological, virological, and histological examinations revealed no disease agent. Further tests are underway.



Chinook salmon fingerlings with extensive lymphoid hyperplasia (upper fish of each pair) contrasted with normal fingerlings (lower of each pair). The external clinical signs (top photo) are similar to those of bacterial kidney disease, and the kidney is extensively swollen (arrow, bottom photo). (Western Fish Disease Laboratory photo)

Western Fish Nutrition Laboratory

Feeding salt enhances saltwater adaptability in salmon.—Survival of juvenile salmon in salt water de-

pends on proper development of the physiological processes responsible for maintenance of normal body functions in the hypertonic saline environment of the ocean. Young coho and chinook salmon were fed diets containing added salt (sodium chloride) by personnel of the Oregon Fish Commission at the Sandy, Oregon, Field Laboratory, in an experiment designed to investigate the effect of ingested salt on the enzyme system responsible for salt transport across gill membranes, and on saltwater survival. Diets containing 2-8% added salt fed to coho and chinook salmon resulted in significant increases in gill sodium, potassium-stimulated ATPase activity (the enzyme activity responsible for salt balance), and increased saltwater survival of young chinook salmon. The effects of salt feeding were still present 2 weeks after removal of the salt-supplemented diets, but had essentially disappeared after 4 weeks. Chinook salmon receiving no food for 2 weeks before introduction into salt water had a much higher mortality rate than those receiving the control diet up to the point of saltwater exposure. The results suggest that incorporation of salt into the diets of juvenile salmon for several weeks before release may have a beneficial effect on saltwater adaptability for 2 weeks to 1 month after release.

Differences between spring and fall chinook salmon.—Adult spring chinook salmon begin returning to the Columbia River in April and spawn in August, whereas fall chinook salmon begin to return in August and spawn in September. Young spring chinook salmon are generally kept in the hatchery for about 16 months before release, but young fall salmon are released in May of the 1st year, at about 4 months of age. In 1974, biologists of the Abernathy Development Center, by rearing fish in warmed water, produced larger than normal juvenile spring salmon for release in June as underyearlings. The objective was to determine if the normal rearing period of 16 months could be shortened to about 5 months. These fish were sampled periodically and tested by scientists at the Western Fish Nutrition Laboratory for smolt characteristics and saltwater adaptability. As compared with juvenile fall chinook salmon of the same size, the spring fish showed less gill sodium, potassium-stimulated ATPase activity, and higher mortality when subjected to salt water at 33-34°/oo. A small group of the spring fish held at 9°C for 1 month had a much better survival rate in salt water than did those held at 16 to 17°C. These results suggest that there is a major difference between juvenile fall and spring chinook salmon in the ability to become physiologically prepared for conversion to salt water as underyearlings, but that the spring-run fish may be ready for the transition if their growth is accelerated by rearing in warm water and they are then transferred to cold water for a suitable interval before being exposed to salt water.

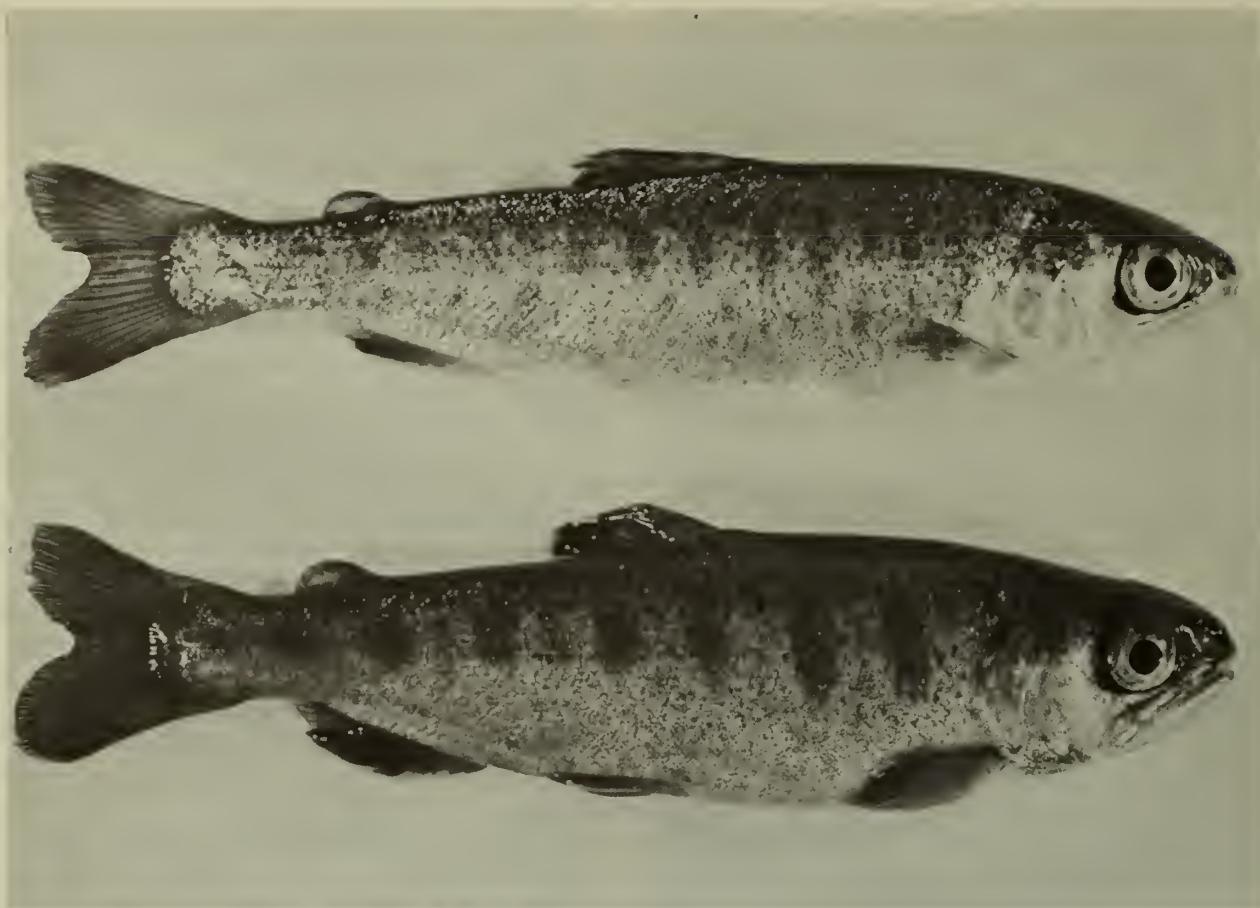
Dietary methyltestosterone interferes with saltwater conversion in coho salmon smolts.—Methyltestosterone (30 µg/g) in the diet of coho salmon smolts for 2 months caused a decrease in gill ATPase activity and resulted in 75% mortality when the fish were stressed in salt water at 36°/oo for 15 hours. There was no mortality among control fish. The results suggest that more detailed investigations should be conducted into the use of this hormone for possible prevention of skin diseases in salmon smolts.

Use of modified raceways for determining migratory movements.—In a test of migratory movements, 400 coho salmon were placed in late March in the upper pond of a hatchery raceway that had been divided into a series of five holding ponds. A roof over part of the upper pond provided cover for the salmon being tested and a screen on the uppermost dam prevented downstream movement. After about 10 days, the screen was removed to allow downstream movement at will. There was no significant movement until 3 weeks later, starting about 1 May, when small numbers of fish moved downstream at night. Peak movement occurred during the last week of May. This system will prove useful in correlating actual migratory movement with the observed elevation in gill ATPase activity during parr-smolt transformation, and in establishing the exact time when the fish develop migration tendencies.

Migration and sea water adaptation.—Improved fishing methods and man's use of the world's waterways for other purposes have drastically reduced the natural migrations of many anadromous fish. It has become impossible to fully maintain fish populations, and some important species have declined alarmingly. Successful rearing methods and diets have been developed for steelheads and some Pacific salmon, but major problems still lie in the seaward migration of the young smolts and their adaptation to sea water. It is in this migratory phase of the life cycle that man's alterations of the natural environment have had their greatest effect.

Evaluation of premigratory treatments on the successful conversion of smolt salmonids to sea water continued at the Marrowstone, Wash., Field Station. The observation of 101 adult chum salmon, 199 coho salmon, 53 steelhead trout, and 31 sea-run cutthroat trout moving through collecting weirs operated in Chimacum Creek between 1 December 1974 and 1 April 1975 demonstrated the effectiveness of this stream for testing small groups of experimental fish. Six of the returning steelheads (released in spring 1973) were marked, but tags were not recovered. (A double marking system used for juvenile salmonids released in 1974 and 1975 should result in more positive identification.)

Two groups of juvenile steelheads were tagged and released in March and April 1975. A bacterial gill infec-



Coho salmon smolts fed dietary methyltestosterone (30 ng/g diet) for 2 months (lower fish) had more skin pigmentation, darker parr marks, and greater weight than normal salmon (upper fish). Also, the treatment lowered gill sodium and potassium-stimulated ATPase activity and decreased survival rates of fish transferred to salt water.

tion in May prevented the release of the third group of tagged smolts. Treatment of these fish resulted in deactivation of the gill ATPase enzyme and the inability of the fish to successfully convert from fresh water to salt water. Tests are continuing because the chemical used is also commonly applied as a herbicide to control aquatic vegetation.

Preliminary tests have demonstrated the effectiveness of this variable-salinity field station for studies of environmental physiology and for screening potential migratory and food conversion problems of the young salmonids.

Clinical osmometry.—In experiments designed to evaluate the usefulness of clinical osmoregulatory measurements as indicators of environmental stress and the nutritional status of coho salmon, biologists of the Western Fish Nutrition Laboratory observed such a dramatic change in the water content of plasma between normal fish and fish stressed by a variety of means—temperature changes, dewatering, pursuit, and handling—that they

believe that the simple, gravimetric determination of the water content of plasma may be a useful diagnostic tool. Normal coho salmon have a plasma water content ranging from 91-93% for young of the year to 89-91% for 2-year-olds. Under conditions of stress the plasma water content has been observed to drop as low as 67%, suggesting a shift of water into the extravascular space.

Clinical chemistry.—The objectives of a completed test on coho salmon were to determine the approximate normal ranges for several clinical characteristics and to observe how the ranges change with diet, temperature, and developmental stage or age. The study consisted of rearing coho salmon on two different diets (Oregon Moist Pellet and H440 standard test diet) and at two constant temperatures (5° and 10°C). Fish blood and liver tissue were obtained monthly, from the 7th through the 17th month. Characteristics measured were length, weight, hemoglobin hematocrit, serum cholesterol, total serum protein, serum albumin, total serum lipids, blood urea nitrogen (BUN), and liver glycogen. Values that varied



Modified hatchery raceway used to ascertain when downstream migration tendencies develop in coho salmon smolts.

according to the diet fed, regardless of temperature, were cholesterol, total serum protein, BUN, total lipid, and liver glycogen. Differences related to temperature were observed for hematocrit, serum albumin, BUN, and liver glycogen. All characteristics exhibited differences of varying degrees with developmental stage or fish age. Length and weight, or growth indices, showed that a phenomenon known in hatcheries as the "winter doldrums,"

a period of little or no growth from November through January, normally attributed to low water temperature, is also evident at a constant 10°C rearing temperature. Some blood chemistry characteristics changed dramatically from November through January. One fact brought out by this study was that in evaluating fish health or physiological state, one needs to be keenly aware of the many factors that affect the clinical characteristics being measured.

ENDANGERED SPECIES

Cui-ui Lake Sucker Project

Culture of the cui-ui sucker.—Personnel of the Division of Cultural methods Research have developed facilities and techniques for artificially culturing an endangered species of the sucker family, the cui-ui ("kwēe-wee"). A hatchery constructed on Hardscrabble Creek (in the Paiute Indian Reservation, Pyramid Lake,

Nev.) has the capacity to incubate nearly 2 million eggs at one time and to hold the fry until swim-up, when they are released into Pyramid Lake. A total of 6.7 million fry were released during fiscal years 1973-75.

Various tribal members have received training in all phases of the cultural program and are expected to assume operation of the artificial culture program by fiscal year 1976, when the Research Division will withdraw from the



The endangered cui-ui (*Chasmistes cujus*), a fish of the sucker family. This individual is a female weighing 6 pounds.
(Photo by E. A. Pyle)

project. The Division of Technical Services, Reno, Nev., will continue to provide technical support as needed.

Standard culture methods used for trout are satisfactory for cui-ui, with three exceptions: (1) Females, unless given injections of pituitary gland, ripen sporadically or not at all; spawning success has been as low as 5%. Intraperitoneal injection of 0.02 g ground carp pituitary gland suspended in 1.0 ml of normal saline per female has resulted in spawning success as high as 92%. Males have responded better to intraperitoneal injections of veterinary grade chorionic gonadotropin at the rate of 1,000 units per individual. (2) Cui-ui eggs are not as delicate as trout eggs, and a gentle rolling motion during incubation seems to be beneficial. Daily treatments with formalin at the rate of 1:800 (in flowing water) for 15 minutes are necessary to control fungus. (3) Although attempts to rear cui-ui beyond the swim-up stage in hatchery troughs have been largely unsuccessful, the fish grow very well in ponds with a minimum of care. Construction of enough properly designed ponds to rear a large number of cui-ui to a size



The hatchery at Hardscrabble Creek, Nevada, where the cui-ui is raised. (Photo by E. A. Pyle)

relatively safe from predation within the lake is recommended.



A Florida manatee in its natural habitat. Service biologists are conducting a variety of studies on this species to obtain information for its preservation. Of interest is the development of techniques for aging and sexing manatees based on data collected from animals that have died naturally or accidentally. (National Fish and Wildlife Laboratory photo)

The Marble Bluff fishway will be operational during spring 1976. If it is successful, the artificial culture program can be terminated, the facilities at Hardscrabble Hatchery razed, and the site returned to its original state.

National Fish and Wildlife Laboratory

General biology of the West Indian manatee.—The West Indian manatee is large in size, fusiform in shape, and thick-skinned with little hair. The forelimbs are modified paddles with rudimentary nails, and the spatulate tail is horizontally flattened. Adults range in size from 2.5 to over 4.5 m in length and corresponding weights vary from 200 to 600 kg. However, average adults are between 3 and 4 m in length and weigh less than 500 kg. Sexual dimorphism in size has not been documented. Breeding occurs throughout the year, and the cow is polyandrous, allowing

several bulls to mate with her during her relatively short period of receptivity. Mating has been observed in water about 2.5 m in depth as well as in shallows less than 1 m deep. The gestation period is probably about 385-400 days and parturition is thought to occur in secluded shallows. Successful breeding has occurred in captivity only once, but the event was not fully documented. Although one is the usual number of young, twins and a case of foster parenthood have been recorded. Newborn calves may measure over 1 m in length and weigh between 11 and 27 kg. Suckling from the pectoral teats occurs underwater. Calves may begin grazing within weeks of birth, but intermittent nursing may continue for 1 or 2 years. Therefore, breeding probably occurs every 2.5-3 years. Transition to adulthood is gradual and sexual maturity may not be attained until 4 or possibly 6 years of age. Manatee longevity in the wild is unknown, but a captive lived in Florida for 23 years.

Preliminary studies of social behavior indicate that the most obvious close bond is between cow and calf. Manatee bulls may associate with a female in estrus for a week to more than a month. Small herds of less than 10 animals are the most commonly encountered groups except during cold winter periods when as many as 75 animals may congregate in warm water or protected areas in southern Florida. Intragroup social interactions, including "play" and nonspecific sexual behavior (including homosexual), have been reported.

No specific daily patterns of behavior have been reported for the West Indian manatee. Adults may spend from 6 to 8 hours daily in feeding. Manatees are completely herbivorous, consuming a variety of food plants in the following order of preference: (1) submerged plants, (2) surface floating vegetation, and (3) emergents. Quantities of insect larvae, amphipods, mollusks, shrimp, and other invertebrates, ingested incidentally while feeding, probably provide necessary amounts of protein for manatees. Captive adults consume 30-50 kg of vegetation each day. It has been suggested that manatees must return to fresh water occasionally for drinking.

Internal parasites of the West Indian manatee include two trematodes (*Opiosthotrema* and *Chiorchis*) and one nematode (*Plicatolabia*). A single copepod (*Harpacticus*) was also reported on the skin. Manatees in salt water become covered with marine diatoms (*Zygnema* and *Navicula*) and barnacles, whereas animals remaining in fresh water develop a coat of algae (*Lynghya* and *Compsopogon*). Manatees appear to be susceptible to pneumonia and other bronchial disorders when exposed to unusually low temperatures. To date, predation on the manatee by any animals other than man has not been documented. Crocodilians and sharks have been suggested as possible predators.

Known distribution of the African manatee.—African manatees occur in coastal waters and in adjacent rivers along the coast of West Africa from the mouth of the Senegal River to the mouth of the Cuanza River in Angola. They have been reported from the Faleme, Gambia, and Casamance rivers of Senegal and Gambia, and from the coasts of Guinea. Other rivers known to support manatees are the Sierra Leone, Missunado, St. Paul, and Cavalla rivers. In Ghana, manatees are now apparently restricted to Lake Volta and the upper reaches of the Volta River. They have been taken at Benin and Lagos, Nigeria, and are numerous in most of the larger rivers of southern Nigeria. They are found in the Niger River, commonly as far upriver as Idah. Occasionally they travel even further upriver, and have been noted in Segou, Mali, approximately 200 miles southwest of Timbuktu. Manatees also ascend the Benue River, a large tributary of the Niger, and have been reported in this waterway as far east as Numan.

They are not believed to occur in Lake Chad, although specimens have been collected from its principal tributaries, the Baningi, the Bahr Keeta, and the River Chari. In Cameroon, manatees are found in the Korup Reserve and have been reported from the Mongo and Wouri rivers. Probably they also inhabit the Campo River in southern Cameroon. Specimens have been taken from the Rio Muni, Gabon, and Ogooue rivers and the species may also be found in the Loeme River of Congo Brazzaville. In Zaire, African manatees occur in the lower Congo River, and also in the upper drainage of the Uele River, east to Kibali. The Loge, Dande, Bengo, and Cuanza rivers of Angola all reportedly contain manatees. No migrational movements have been noted for this species.

Abundance of the Amazonian manatee.—The Amazonian manatee was formerly abundant in the Brazilian Amazon. Thousands of skins were brought yearly to Manaus for trade in the 1930's and 1940's. The species is, consequently, rare today in most of the Amazon and its tributaries. It is, however, still fairly common in some lakes on the lower Tapajos River and in the Nhamunda River. In general, this manatee is regarded as rare in Colombia. This species is nearer to extinction in Peru than any other mammal, although modest numbers do remain in the Rio Samiria and the Rio Pacaya. All reports indicate a dramatic decline in numbers of the Amazonian manatee throughout its range. Population estimates are not available, but extinction has been predicted within the next few decades if local hunting pressures continue.

Human disturbance to dugong populations.—Biologists of the National Fish and Wildlife Laboratory have assembled a report on the distribution, status, and natural history of this species. Man is the major threat to the dugong's existence. Boat traffic in offshore areas may inflict mortal wounds. Increased marine fishery activities in the India-Ceylon area have resulted in accidental nettings, drowning substantial numbers of dugongs. Dynamiting for fish is also assumed to affect dugongs adversely. In Queensland, Australia, a shark netting program has resulted in much dugong mortality; similar netting programs exist in Africa.

Dugongs have been hunted throughout their range. The meat is similar to veal or pork and keeps for long periods of time. Average sized adults yield from 5 to 8 gallons of oil similar to cod liver oil, and the hide makes excellent leather which is especially suitable for making sandals. Tusks and bones are used as ivory and several body parts were once thought to have medicinal or aphrodisiac properties. Today, hunting pressures are much reduced, in part because of the decline of dugongs, but poaching continues in spite of legislative protection. In Australia, the aborigines and Tores Islanders may still legally hunt the animals, and one village of 250 people caught an average



Captive dugong at Mandapam Camp, India. Dugongs are herbivorous mammals of tropical and subtropical coastal waters in the Indo-Pacific region. They are captured for meat, oil, bones, and hides and, as a consequence, have become extirpated from many areas. (Photo courtesy R. S. Lal Mohan)

of about 70 animals per year during the early 1960's.

The dugong is totally protected in Egypt, Anglo-Egyptian Sudan, Ethiopia, Somalia, Kenya, Tanzania, Mozambique, Madagascar, South Africa, Natal, India, Ceylon, Sabah, Sarawak, the Philippines, Japan, Formosa, New Caledonia, and Australia. While protection is nearly complete, effective enforcement is virtually impossible.

Patuxent Wildlife Research Center

Florida everglade kite production.—The Florida everglade kite was formerly abundant in the freshwater marshes throughout peninsular Florida. The present range of this bird is much reduced; it now occurs principally in the marshes on the southwest side of Lake Okeechobee and the headwaters of the St. Johns River southward into the northern part of the Everglades National Park.

Ten censuses, completed since 1969, averaged 82 kites observed per census. Total numbers have ranged from 44 to 120 kites and 95 were recorded on the latest census. Museum collections in the United States, Canada, and Europe contain 298 specimens of everglade kite material from Florida. Since the spring of 1968, 57 nestlings have been banded with combinations of colored leg bands to facilitate plotting the movements of individual birds. Ten nestlings were color-banded in the spring of 1974. Nesting success was very low in 1974; young were fledged from only 11% of the nests. Predation and bad weather accounted for most of the nesting failures. All of the successful nests were at Lake Okeechobee and had been moved to artificial nest structures.

First South American snail kite reared.—For 3 years, attempts to raise offspring of captive snail kites were unsuccessful. During that time, 45 chicks hatched, but only one of them survived beyond the age of 6 days. The excessive mortality was probably caused by disease, nutritional problems, or both. Potential pathogens were isolated, and most chicks showed signs of a progressive weakness and anemia before death. Treatment of this condition with antibiotics has not been completely effective, although the lives of some chicks have been prolonged. In 1974, a combination of antibiotic medication and fresh liver in the diet produced a marked improvement, but the diet appeared to lack mineral balance. A chick was reared on a semibalanced diet involving the addition of calcium carbonate and restricted feeding. This chick is the first of its species known to have been successfully hatched and reared in captivity. Several additional chicks were hatched and seven survived in 1975, when an antibiotic, Genomycin, was used to reduce *Pseudomonas* (a bacterium) infections.

Dusky seaside sparrow population.—Continuous or nearly continuous freshwater inundation of salt marshes on the Merritt Island National Wildlife Refuge has provided excellent mosquito control and has favored waterfowl, wading bird, and shorebird use. It has, however, been detrimental to the dusky seaside sparrow. Die-offs of the emergent saltmarsh vegetation have been noted in most impoundments. The decline of saltmarsh cordgrass, saltgrass, and several obligate halophytes has been accompanied by a rapid decline in the population of dusky seaside sparrows on Merritt Island.

Four censuses of singing males were conducted in two areas on the Refuge in 1974. These censuses revealed only two singing males, the same number observed in 1973. Habitat manipulation by burning the marshes, removal and control of shrubby vegetation, and control of water levels should have great promise for improving the habitat for dusky seaside sparrows.

Study area for masked bobwhite experimental releases.—A 1840-acre area in the former, southern Arizona range of the masked bobwhite has been leased from the State for 5-7 years. Grazing on the area was deferred, and the response of vegetation to deferment and the survival of masked bobwhites released in the wild will be evaluated. In the year that has elapsed since grazing was discontinued, grass and forb growth has recovered and promises to provide conditions more comparable to optimum masked bobwhite habitat in Sonora, Mexico.

Most of 347 masked bobwhites released from May through October 1974 remained in the general area of release, although one pair was observed more than 2 miles from the release site. No evidence of reproduction was observed in 1974, possibly because holding facilities on



Elevated blind for studying Hawaiian crow nesting habits on Mt. Hualalai on the island of Hawaii. (Photo by W. E. Banko)

the experimental area were not completed early enough for the quail to be shipped from Patuxent before they came into reproductive condition. The construction of a storage and workshop building and pens to hold several hundred birds, and the placement of a mobile home on the experimental area, will facilitate early shipment of birds and local observation and conditioning of stock to weather, predators, and natural food items. These improvements should enhance the future success of releases.

Kauai endangered bird surveys completed.—The status and distributional surveys of the endangered birds of Kauai were completed during 1974. During the final year of the surveys, the Kauai oo, ou, omao, puaiohi, and nukupuu were observed. Of the six endangered forest birds on Kauai only the akialoa has not been seen since the study began in the summer of 1968.

Future studies of Kauai birds will emphasize life history. For the 4th consecutive year, a pair of oo were located, but, apparently, they did not nest during the summer of 1974. Based on knowledge of the Kauai oo's daily pattern of calling, its territory size during the nesting period, and its distribution, it is believed that there are only about 50 birds left to represent the family Meliphagidae in Hawaii.

Laysan ducks recovering.—Biologists in Hawaii were encouraged when they found a total of 69 Laysan ducks on Laysan Island on 18 July 1974. The highest previous count of only 24 Laysan ducks in July 1973 represented the lowest point of a decline that started in 1968. The Laysan duck's productivity seems to be related to the water level of the lagoon. Installation of meteorological and water-level recording equipment at Laysan Island may help to provide clues to factors influencing their numbers.

Puerto Rican parrot studies.—Although the number of captive Puerto Rican parrots showed a net increase of one bird in 1974, the wild population dropped by two individuals, and the total population of the species dropped from 25 to 24. The wild population decreased despite fledging of three young in June and apparently involved the loss of three adults and two of three fledged young. One 18-year-old captive bird held by a private citizen in San Juan also died this year. As of June 1975, no mortality has been suffered by the captive birds held by the Endangered Species Project. The seven captives at the Puerto Rican Field Station, including two taken as eggs this year, have been installed in a newly constructed aviary. These birds, representing three family lines, may be too young for reproduction. The three captives at Patuxent are older birds and represent two family lines. The Patuxent captives produced no eggs in 1974.

The two active nests in 1974 were successful in fledging young, but one would probably have failed except for nest-site improvement. This pair occupied a hole with a

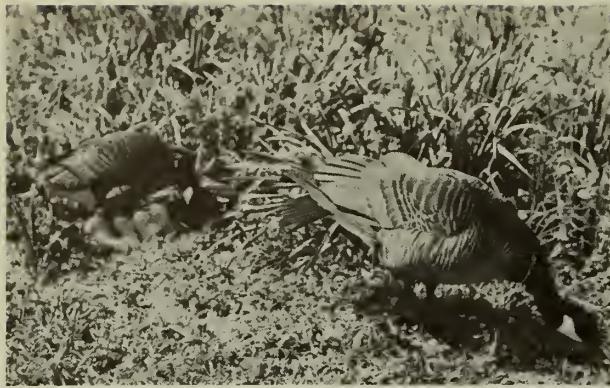


Half-grown Puerto Rican parrots raised by hand in 1973. In this species development from hatching to fledgling takes approximately 2 months. (Photo by Helen Snyder)

wet muddy bottom. Before egg-laying and once later in the breeding season the cavity bottom was covered with dry Colorado earth; this precaution served to keep the cavity bottom relatively dry during the breeding season. However, because of the danger of flooding and vigorous harassment of this pair by pearly-eyed thrashers, both eggs laid by the pair were incubated artificially at the field station while the adults continued to incubate artificial eggs. The real eggs were fertile and developed to the hatching stage, but only one hatched. Shortly after hatching the chick was replaced in the nest hole. It was immediately accepted by the adults and fledged 9 weeks later.

In 1974 considerable study was given to natural enemies of the parrots. An unexpected finding was the high incidence of warble fly parasitism of birds in Luquillo Forest. One parrot nestling was infested with these parasites in 1974, but it survived. Twenty-five of 35 pearly-eyed thrasher nests were parasitized and 16% of the afflicted young died.

Aleutian Canada goose release monitored.—A team of biologists camped on the remote Aleutian Island of Agattu, Alaska, to study the 41 Aleutian Canada geese released there in March 1974. All birds had been wing-clipped to render them flightless during the breeding season. By 8 June two pairs were incubating eggs and six additional pairs were defending territories. By 27 June there were five known nests on Agattu. Production of young in early July in two of the nests represented an important milestone in the restoration program. Leg bands of two adults were recovered near Humboldt Bay in north-



Pair of Aleutian Canada geese and nest at the Patuxent Wildlife Research Center. This species is being propagated to re-establish breeding populations on certain islands of the Aleutian Chain. (Photo by R. C. Erickson)

ern California, indicating successful southward migration.

At Patuxent 13 pairs of Aleutian Canada geese produced 115 eggs, of which 59 (52%) were fertile. Twenty-six hatched, and all were raised and will be used in future release programs in the Aleutian Islands.

Timber wolf studies.—Scent-marking by wolves was studied in Minnesota by 150 miles of ground-tracking in winter. The mean rate of scent-marking was about once per 450 yards, and this was usually in response to an existing mark, not necessarily from a strange wolf. The marking rate increased with the approach of the breeding season, peaked during the mating season, and dropped off within a few weeks thereafter. On the average, each traveling wolf detected one scent mark every 3 minutes.

Four wolves, equipped with radio transmitters, were transplanted from Minnesota into Upper Michigan during the winter of 1974-75. The wolves settled down in Michigan after a period of exploration and apparently accepted their new environment. However, one-by-one they were killed by humans. This experiment demonstrated that wolves can be transplanted without homing, that they can survive natural aversive factors, and that human intervention is preventing the repopulation of Upper Michigan by wolves.

An intensified breakdown in the territorial organization of the wolf population in the Superior National Forest during winter 1974-75 resulted in the deaths of at least two wolves. In two observed cases trespassing packs encountered others and fought. Trespassing into neighboring territories has intensified because of a drastic decline in deer numbers resulting from a series of hard winters.

Captive whooping cranes at Patuxent.—During spring and summer, observations on the social behavior of the

four breeding pairs of whooping cranes disclosed consistent differences between males and females in the visual and audible portions of an important display, the "unison call." This display is a duet given by the pair (or by several birds in groups) during courtship and territorial defense. The call is now being used to sex whooping cranes at Patuxent.

One pair of whooping cranes, hatched in 1968, produced three eggs in 1975, the first ever laid by a bird hatched and reared in captivity. Of two fertile eggs, one hatched on 29 May, but the embryo in the other died early in its development.

Crane chicks respond to color stimuli.—Because newly hatched crane chicks under natural conditions pur-



Four wolves were successfully transplanted from Minnesota into Upper Michigan. (Top) A tranquilized wolf is brought in from a Minnesota trapline for shipment. (Bottom) A Minnesota wolf is measured before it begins its 300-mile trip to Michigan. (Patuxent Wildlife Research Center photos)



The "unison call" display by adult whooping cranes. The male is at the left and the female at the right. (Photo by C. B. Kepler)

sue or are fed a wide variety of insects and other small invertebrates, they are unresponsive at first to the prepared diets fed at Patuxent. Moist dog food has been offered to young cranes, either from the hand or a spoon, to induce them to eat, but this can lead to difficulty in feeding, improper nutrition, hunger, interspecific aggression, and even improper imprinting. A series of behavioral experiments was undertaken to develop an effective means of inducing hatching cranes to eat formulated starter mash and pellets with minimal human interaction. In June 1974, five sandhill crane chicks less than 60 hours old were tested for their responsiveness to different colors, utilizing their normal pecking response. The chicks were presented with a randomized sequence of black, gray, white, red, yellow, green, and blue $\frac{1}{2}$ -inch dowels. Each dowel was presented, in turn, to the chicks at eye level; the number of pecks delivered at the dowel in a 30-second period was tallied, beginning after the first peck (which was not counted). The chicks delivered 1,162 pecks in 11 tests with the following results: red, 237; yellow, 194; black, 166; green, 152; blue, 135; and gray, 119.

Red $\frac{1}{2}$ -inch dowels were held at eye level in front of five chicks that were the first hatched of a group and were gradually moved to food dishes when the chicks began to follow them. Then the dowels were waved above the dishes or slightly immersed in the crane starter mash. All of the chicks eagerly pecked the dowels, the force of their strokes carrying their bills into the mash which was then eaten. The five chicks learned to feed in less than 1 hour in the experimental situation. The remaining six chicks that

hatched later were not exposed to the experimental sequence. Instead, the dowels were placed upright in the food dishes and the chicks learned to feed from the mash directly.

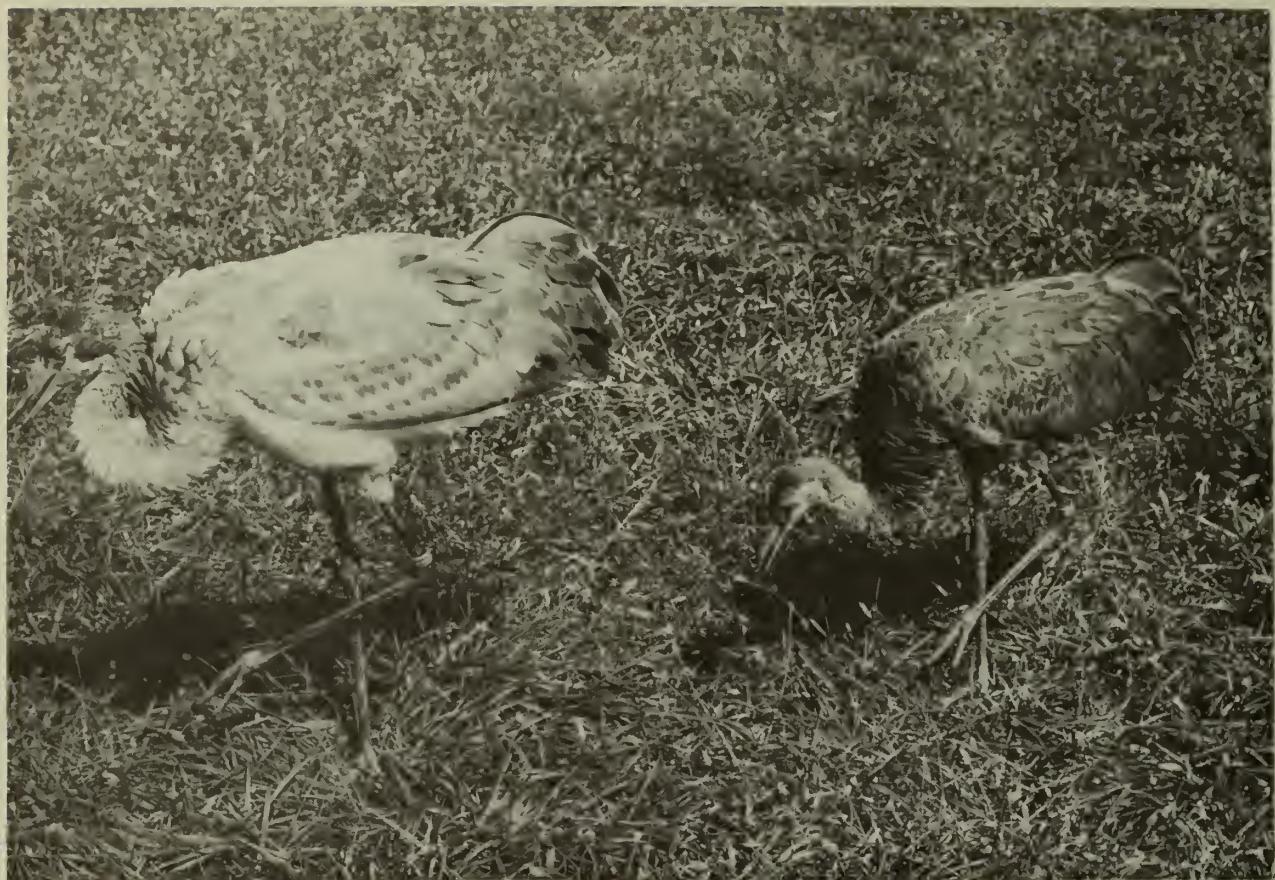
Four races of sandhill cranes bred at Patuxent.—Egg production, fertility, number of chicks hatched, and number of chicks reared improved in 1974 for all four subspecies of sandhill cranes kept at Patuxent. Two pairs of Mississippi sandhill cranes, a subspecies seriously threatened in the wild, laid 13 eggs, one of which hatched. The chick developed normally although the yolk sac was improperly resorbed. This is the first successful captive rearing of an individual of this race. A single pair of lesser sandhill cranes produced one egg which hatched; this also is believed to be a new breeding record for this subspecies. All four subspecies at Patuxent have now bred. A hatch of 25 and 32 chicks, respectively, of greater and Florida sandhill cranes resulted from 174 eggs laid. These chicks will be used in attempts to reestablish populations in the wild if facilities can be developed to condition them properly before release.

Four eggs of the Mississippi sandhill crane were collected in southeastern Mississippi and shipped to Patuxent this spring. All of them hatched. One chick died from chilling during the 1st week of life, and the other three survived, increasing the number at Patuxent to 12.

Experimental hybridization of cranes.—The substitution of whooping crane eggs for sandhill crane eggs is under consideration to establish new whooping crane populations in areas of the species' former range where sandhills breed. Such a method raises many questions, including the possibility that the young whooping cranes may become imprinted on their foster sandhill parents, and later in life may attempt to pair with sandhills. Can crossbreeding occur, and if so, will hybrids develop normally? Will they be viable and attempt to backcross with either parental type? In order to avoid intrusion of whooping crane genes into sandhill populations, these and related questions must be answered.

This spring a single Florida sandhill crane female was inseminated with semen from CAN-US, a whooping crane picked up as an injured bird in Wood Buffalo National Park in 1964. A single, robust hybrid, pale gray above, white below, and intermediate in height between the parents has been raised. The hybrid is easily distinguished from either parental type and appears to be intermediate between them in behavior and appearance. The behavior of the hybrid will be closely monitored in the coming years and its choice of species for a mate ascertained. If natural breeding does not occur, artificial insemination will be used to determine if the hybrid is fertile.

Nutrient requirements of animals studied.—The nu-



Crane chicks approximately 4 months old. The chick at the left is the offspring of a female Florida sandhill crane artificially inseminated with semen from a male whooping crane. The chick at the right is a normal-plumaged Florida sandhill crane from the same female. The experiment was carried out to ascertain the viability of the whooping crane's sperm and to reveal the physical characteristics of a hybrid of these two species, should one be encountered in the wild. (Photo by R. C. Erickson)

trient requirements for most species of endangered wildlife are not known; formulating their diets, therefore, is a difficult task. Studies are in progress with related species to determine pertinent nutrient requirements that can be used in developing rations for endangered species. Laboratory studies of bobwhite quail have been conducted to estimate their requirement for methionine, an essential

amino acid. Trials have shown that bobwhites require no more than 0.6% methionine in the diet for satisfactory growth. Although this amino acid is scarce in the ingredients of feed commonly used in diets for avian species, it can be prepared commercially and can be added to rations to provide sufficient methionine for the well-being and growth of quail.

GREAT LAKES FISHERIES

Fish Control Laboratory

Sea lamprey control research.—Applications of the lampicides, TFM and Bayer 73, have reduced populations of sea lampreys in the Great Lakes to very small percentages of pretreatment numbers. Although both

compounds are highly effective, neither of the lampicides has yet been fully registered. As part of the program to satisfy registration requirements, researchers at the Fish Control Laboratory studied the persistence of TFM in fish tissue. Yellow perch and carp exposed to 1 mg/l of TFM for 12 hours at 12° C accumulated 0.12 and 0.4 µg/g,

respectively, in muscle tissue. Residues dropped rapidly after the fish were transferred to fresh water and were 0.04 and 0.02 $\mu\text{g/g}$ after 24 hours in untreated water.

Coho salmon eliminate TFM in their bile or urine. Urinary levels of conjugated TFM after exposure to 3 mg/l for 4 hours peaked at 61.5 mg/ml within 4 hours after the fish were transferred to fresh water. This experiment helps explain the rapid elimination of TFM from fish tissues and supports the contention that the residues are not persistent in edible fish.

The presence of other environmental contaminants sometimes produces toxic effects far in excess of those normally expected from a chemical application. Certain compounds may also negate the activity of applied materials. Rainbow trout, coho salmon, and green sunfish were used to test the effects of prior exposure to salicylamide on the toxicity of TFM. When the test compounds were applied separately or in sequence, no effects on the toxicity of TFM were observed; however, the simultaneous occurrence of salicylamide and TFM greatly increased the toxic effects of TFM in the trout and salmon.

Concern has been expressed over the possible entry of TFM into human or animal water supplies. Activated carbon (charcoal) effectively removed TFM from treated waters. Adsorptive capacity of charcoal was not affected by temperature but increased fourfold when pH was reduced from 7.5 to 6.5.

Detoxifiers would be useful in the unlikely event of a TFM spill or accidental overdose. Potassium permanganate at 1 mg/l, chlorine at 0.5 mg/l, and sodium thiosulfate at 10 mg/l all failed to reduce the toxicity of TFM to green sunfish during a 6-hour contact period; rather, their addition to TFM solutions increased toxicity.

The original research protocol developed for the collection of data needed to support continued registration of TFM as a lampricide was completed during the year. The data will be submitted to the Environmental Protection Agency to determine their adequacy for demonstration of safe and effective use of TFM in the Great Lakes Basin.

Ecological effects of Bayer 73 were part of a continuing study on this lampricide. Toxicity tests involving non-target organisms revealed that prawns (*Palaemonetes kadiakensis*) were the most resistant invertebrate species tested. Lymnaeid snails were 19 times more resistant than *Helisoma* sp. to Bayer 73.

Exposure of frog eggs to concentrations of Bayer 73 greater than 0.2 mg/l resulted in no hatch. At 0.01 mg/l or less, eggs developed and hatched normally.

Antimycin as an alternate control for sea lampreys.—Testing was continued to evaluate the efficacy of delayed-release antimycin as a control for sea lamprey larvae in delta areas where the lamprey-producing streams enter lakes. Previous tests of this formulation, calculated as 300

$\mu\text{g/l}$ of antimycin applied in the bottom 2 inches of water, had given about 90% control. The 1974 trials involved use of 150 $\mu\text{g/l}$ in the bottom 2 inches in an attempt to define the minimum effective treatment rate.

Trials were conducted on the perimeter of the deltas of two Michigan streams—Bismark Creek and the Ocqueoc River (flow, about 50 cubic feet per second). Ammocetes were placed on the bottom in cages with pans full of sand to permit the lampreys to burrow. Fish were caged at selected distances above the bottom. In addition to the observed mortality of caged specimens, the effectiveness of both trials was further evaluated by follow-up applications of Bayer 73 (a chemical which drives lamprey larvae to the surface of the water) and by divers who inspected the lake bottom for additional ammocetes in the treatment area.



A 15-inch rainbow trout being attacked by a 16.5-inch sea lamprey in an aquarium at the Hammond Bay Biological Station in Michigan. (Photo by R. E. Lennon)

On the Bismark Creek delta (water temperature, 26° C), all evaluations indicated a kill of more than 95% of the ammocetes in the treatment area, including 1,000-1,500 uncaged wild larvae. On the Ocqueoc River delta (water temperature, 10° C) the mortality of caged larvae was 66%. Few dead wild larvae were found. Treatment with Bayer 73 revealed a significant number of resident larvae left alive after the antimycin treatment. The lower temperature in Ocqueoc Lake probably increased the required effective contact time for lampreys, and the chemical presumably dispersed into surrounding water before a lethal dose could be absorbed by the ammocetes. A higher initial concentration will probably have to be used in cold water. The complete kill of larvae in 50% of the cages and complete survival in 25% also indicated that distribution of the material was not uniform.



Retrieving a midwater trawl, one of an array of tools used by Fish and Wildlife Service biologists to survey the Great Lakes fishery resources.
(Great Lakes Fishery Laboratory photo)

In the trial at Bismarck Creek delta, 89% of the largemouth bass caged 5-10 feet above the bottom survived. In the Ocqueoc trial all bass survived—even those at the bottom—verifying that distribution of the toxicant was poor.

The data suggest that, with proper distribution, antimycin treatments in the bottom 2 inches of water will effectively control lamprey larvae.

Great Lakes Fishery Laboratory

During fiscal year 1975 the Great Lakes Fishery Laboratory at Ann Arbor, Michigan—including its field stations at Ashland, Wis.; Hammond Bay, Mich.; and Sandusky, Ohio, and its research vessels *Cisco*, *Kaho*, *Siscowet*, and *Musky II*—completed its 47th year of fishery research on the Great Lakes. A staff of about 100 professional and support personnel addressed a wide variety of Great Lakes problems, which ranged from

measuring the impact of smelt predation on herring fry in Black Bay, Lake Superior, to projecting the annual surplus production and allowable catch of walleyes in Lake Erie. Perhaps the principal feature of this collective effort was the comparatively greater degree of interagency coordination and cooperation that characterized it throughout the year.

Arranged on the basis of three disciplinary groupings—resource assessment, ecology and limnology, and physiology and contaminant chemistry—the following statements summarize the Laboratory's major findings and accomplishments in fiscal year 1975.

Resource assessment.—As confirmed by various indices and related observations in 1974, lake trout stocks in Lake Superior continued to progress to the point where once again they will be largely self-sustaining; the abundance of young-of-the-year native lake trout in Wisconsin waters in 1974 (as revealed by catches in experimental trawls) was higher than in any year since monitoring began in 1965. Numbers of large lake trout, and especially



Lake trout, entangled in an experimental gill net, being brought aboard a U.S. Fish and Wildlife Service vessel on Lake Michigan (top). Surveying Great Lakes fish stocks results in a frequent task on board Service vessels—mending fish trawls (bottom). (Great Lakes Fishery Laboratory photos)

the proportion of native (as compared with hatchery-reared) fish, substantially increased during 1974, while sea lamprey wounding rates continued to decrease.

Although overfishing is suspected as a major cause of severely diminished herring stocks in Lake Superior, the invasion by rainbow smelt and their competition with, or predation on, larval herring has been suspect for some time. Studies in 1974 revealed heavy predation on herring larvae by smelt in Black Bay, Ontario, where both species are abundant. In contrast, no evidence of smelt predation was found in the Apostle Islands region of Lake Superior, where herring stocks are much smaller.

A widespread decline in Lake Michigan chub stocks was confirmed by samples taken in 1974 at the same stations surveyed in 1960-61. Moreover, the commercial catch rate for chubs dropped for the 5th consecutive year, and landings were the lowest in 30 years. Through participation in a technical working group sponsored by the Great Lakes Fishery Commission, intensified analysis of the declining chub resource resulted in: (1) a recommendation that the chub fishery be closed until the stocks recover and harvestable surpluses become available; and (2) the development of guidelines for a small (contract) assessment fishery for monitoring the stock's recovery.

Follow-up surveillance revealed that lake trout fed an enriched diet, reared at elevated temperatures, and planted in Lake Michigan in the fall as accelerated-growth fingerlings are surviving better than fingerlings grown at normal rearing temperatures, fed standard diets, and planted in Lake Michigan at the same time.

Extensive surveys of the smelt and alewife forage base in Lake Huron—as essential there as elsewhere in reconstruction of salmonid populations after sea lamprey control—showed continued strengthening of the base; year classes produced in 1974 were nearly as strong as those produced in 1973, and greatly improved over those in 1972. Considerable progress was made in 1974 in better characterizing and quantifying the areal and depth distribution of alewives and smelt through improvements in our integrated assessment system, which consists of the operation of bottom and midwater trawls in conjunction with acoustical fish-detection equipment.

Surveys of Lake Michigan alewives in 1974 resulted in a lakewide estimate of 86 million kg for the biomass of yearling and older fish—specifically that portion of the total stock vulnerable to our sampling gear—as compared with 100 million kg in 1973. The large alewife population has apparently stabilized in the presence of trout and salmon, which represent a combined standing stock conservatively estimated to weigh at least 14 million kg. These surveys also revealed the presence of a strong 1974 class of alewives, which further substantiates the stability of this species in the face of commercial exploitation



Now common throughout the Great Lakes, the introduced alewife provides abundant forage for many game and food fishes. (Great Lakes Fishery Laboratory photo)

exceeding 20 million kg and a salmonid prey demand undoubtedly exceeding 80 million kg in 1974.

Data from assessment surveys and samples of commercial landings documented the worsening decline of the valuable yellow perch resource in Lake Erie; however, cooperative interagency efforts, coordinated by the Great Lakes Fishery Commission, are gradually resulting in improved management of the species. A technical work group is evaluating changes in minimum size limits as an interim measure for greater protection of the resource.

Walleyes of western Lake Erie continue to recover under the moratorium on commercial fishing in both United States and Canadian waters. An outstanding year class was produced in 1974, as determined from our assessment surveys. The Service is also playing a major role in interagency efforts to improve the strategy for walleye management in Lake Erie by developing, through the Great Lakes Fishery Commission, the technical basis for estimating harvestable surpluses and allocating international catch quotas.

Accelerated proliferation of potential threats to fishes in nearshore waters of the Great Lakes—as represented by more power plants, dredge-and-fill operations, and alterations of the habitat caused by water-use projects—necessitated expending more effort in 1974 than ever before on special surveys at various locations in Lakes Michigan, Huron, and Erie. Summaries of our findings are supplied as needed to all governmental agencies with mutual interests or responsibilities in this area of environmental concern.

The compilation of fishery statistics from United States commercial fisheries throughout the Great Lakes continued during fiscal year 1975; more than 200 copies of standard interim and year-end reports were distributed to cooperating governmental agencies.

Ecology and limnology.—Partial analysis of bottom samples collected by biologists in the lower St. Marys River (the outlet of Lake Superior) in 1971-73 indicates that mayfly nymphs in the river's north channel have been obliterated from Sault Ste. Marie, Ont., downstream for a distance of about 15 miles; oil coats the bottom of this portion of the river. Data from recent intensive sampling are expected to define the polluted area more precisely, and will serve as a basis for measuring the recovery of these valuable fish-food organisms when pollution abatement measures are instituted.

Results of a 3-year study of macrobenthos in the lower St. Marys River, where the navigation channel was recently widened and deepened, showed that the dredged substrate was highly consolidated and remained in suspension only a short time. The macrobenthos outside the immediate dredging area was not noticeably affected by this maintenance project.

In response to a request for technical assistance from the U.S. Army Corps of Engineers, baseline surveys were undertaken during 1972-74 of fish and benthos at a site in Saginaw Bay, Lake Huron, where the effectiveness of using waste heat from a steam-electric power-generating plant to reduce ice cover on a major navigation channel is to be determined. These ice-suppression tests are scheduled for the winter of 1975-76, after which the possible effects will be judged from a comparison of biological data produced by the pre- and post-test surveys.

Millions of pounds of zooplankton pass through the cooling systems of steam-electric power-generating stations on the Great Lakes annually. Although most zooplankters are not immediately killed by the elevated temperatures during passage through a cooling system, the long-term effects of sublethal heat shock on these populations are virtually unknown. Preliminary results of studies being conducted at Hammond Bay Biological Station show that populations of *Daphnia pulex* receiving sublethal heat shocks and held under conditions of low food



A major concern of resource managers is the possible consequences of physically altering fish habitat by blasting and dredging to provide for water-borne commerce. (Great Lakes Fishery Laboratory photos)

availability fared more poorly than unshocked, food-deprived control populations.

Larval smelt, yellow perch, lake herring, and lake whitefish have been demonstrated to have maximum sustained swimming speeds much lower than the average water-intake velocity at pumped-storage and steam-electric power-generating stations on the Great Lakes. The implication is that larval life stages of these Great Lakes species are highly vulnerable to entrainment in power-plant intakes located in the shallow, nearshore waters of the Great Lakes.

A field study to determine the usefulness of the compound p,p'-bis (1-aziridinyl)-N-methyl phosphinothioic amide as a chemosterilant for sea lampreys showed that injection of the compound had no noticeable effect on the

spawning behavior or competitiveness of the test lampreys. Complete sterility appears to have occurred in the males, but it is not known whether the females were sterilized. Our results showed, however, that the release of only sterile males is as effective as the release of sterile fish of both sexes.

A study to describe nutrient dynamics and plankton productivity in the nearshore waters along an undisturbed 37-km section of the shoreline of northwestern Lake Huron is well under way. Related field work is aimed at describing the relation between precipitation in the local watershed and nutrient cycles in nearshore waters. Preliminary analyses indicate that the waters of the study area are unpolluted and can be considered to be representative of historically undisturbed "baseline" conditions in the



The lake whitefish again thrives as a major food fish throughout much of the Upper Great Lakes, as a result of suppression of the sea lamprey and of heavy fishing. However, like other native species, it continues to be threatened by uncontrolled alterations of its habitat. (Great Lakes Fishery Laboratory photo)

nearshore waters of the lake.

Physiology and contaminant chemistry.—Work performed during fiscal year 1975 revealed that residues of DDT in Lake Michigan fishes and of mercury in Lake St. Clair fishes have declined as much as 80% since 1970, when the use and disposal of these contaminants was regulated and controlled. Unfortunately, the lack of similar controls for PCB's and dieldrin has allowed the continued presence of elevated residues of these contaminants in Lake Michigan fishes. Mature specimens of lake trout, coho salmon, and bloaters from Lake Michigan still exceed the 5.0-ppm guideline established by the U.S. Food and Drug Administration for PCB's, and average dieldrin residues in the same fish are at or near the guideline of 0.3 ppm. A survey of lead in fishes from each of the Great Lakes indicated that concentrations of this potential contaminant are not currently elevated.

To better evaluate the effects of various contaminants in Great Lakes fishes, researchers developed a method for characterizing and analyzing the enzyme allantoinase in

fish livers. By this method it is now possible to determine the effects of contaminants on this enzyme and hence on nitrogen metabolism in fish.

Basic work showing how constant and fluctuating temperatures affect the development and mortality of eggs of whitefish, lake trout, and Atlantic salmon was completed. The results aided in the development of a mathematical model that predicts the amount of time required for eggs to develop to various embryological stages under different temperature conditions. This model greatly increases our ability to predict some effects of thermal discharges into nearshore spawning and nursery areas of the Great Lakes.

Studies of the effects of temperature on the rates of methylmercury and DDT uptake in rainbow trout showed that temperature elevation increases the accumulation of these contaminants, and therefore that fish living in thermal plumes may develop higher levels of contamination than fish outside the plumes. Other work on the potential interplay of heat and contaminants resulted in

the development of a "shuttle box," in which a test fish can select and regulate the temperature by swimming back and forth between two chambers. Using this procedure, investigators can evaluate the effects of contaminants and other environmental stresses on the ability of fishes to find and maintain preferred temperatures.

With the aim of improving our general understanding of factors governing lake trout production, researchers determined the energy required for trout metabolism by measuring the oxygen consumption of test fish forced to swim in a tunnel respirometer at various speeds and temperatures. Conversion of the resulting data to caloric equivalents, followed by multiple regression analysis, will allow the prediction of energy consumption for lake trout if the weight, activity level, and ambient temperature of the fish are known.

Tunison Laboratory of Fish Nutrition

Vitamin requirements of lake trout.—Inasmuch as work with terrestrial animals has shown that commercial sources of vitamin K may vary in level and stability of vitamin K activity, researchers at the Tunison Laboratory of Fish Nutrition compared the effects of 1 and 2 ppm of vitamin K from two sources (menadione sodium bisulfite

and Hetrazeen) on the density of erythrocytes and on blood coagulation time in young lake trout.

Results of feeding lake trout the two forms of vitamin K for 18 weeks at 14°C suggest that menadione sodium bisulfite is an ineffective source of vitamin K for hastening blood coagulation in lake trout. A dietary level of 1 ppm Hetrazeen apparently is sufficient to insure normal blood coagulation time and erythrocyte levels in young lake trout.

Dietary choline and substitutes.—Although choline is a vitamin known to be required in fish diets, the minimum amount required for maximum benefit has not been determined. Some investigators have recommended 3,000 to 4,000 ppm as safe levels in trout diets. Choline has been shown to prevent fatty livers in some animals, but no such studies have been reported for lake trout, which have a predisposition toward high fat content. Further research was desirable because feed-grade choline, which is commercially synthesized from petroleum products, recently became much scarcer and more expensive.

Two experiments with fingerling lake trout demonstrated that choline was required to prevent fatty livers and support maximum growth. For fingerling lake trout, the minimum requirement was about 1,000 ppm for maximum growth and may be somewhat higher for prevention of fatty livers. It was also discovered that two chemical analogs of choline have full vitamin potency for trout.

INLAND FISHERY MANAGEMENT

Eastern Fish Disease Laboratory

Biologics section established at Eastern Fish Disease Laboratory.—Serological methods, the accepted standard for laboratory identification and detection of microbial pathogens, require the use of reference organisms, specific antisera, and standardized methods. Human and veterinary medicine have centralized sources for such biological reagents and many products are also available from commercial supply houses. As yet, however, no counterpart source exists for serodiagnostic reagents for fishes. Federal and State fish health specialists must prepare their own biologicals, and many field stations are not equipped to produce all that are needed. Consequently, personnel at the Eastern Fish Disease Laboratory have established a biologics section to develop, standardize, and distribute antigens, antisera, and other clinical reagents to Federal, State, university, private, and foreign fishery laboratories.

At the Laboratory, biologists have assembled, identified, and purified the various major microorganisms

pathogenic to fish; the collection is the most comprehensive of its kind in existence, and the pathogens are available to qualified agencies or persons.

Provisional standard methods have been developed for using these organisms to produce specific antisera in rabbits or other appropriate animals, for serological tests. Such tests now include agglutination, precipitation, fluorescent antibody, and serum neutralization. Distribution is made upon specific request, and shipments are accompanied by instructions for proper use and for interpretation of the results. Antisera are now available for six bacterial pathogens, one protozoan, and six viruses.

The Laboratory houses a research reference source for the pathogens themselves; the collection now includes several hundred strains of bacteria, 70 strains of viruses, and 9 cell lines. During the past year, more than 100 requests for various diagnostic reagents and microorganisms were received from biologists in the United States and other countries. Each user is asked for a copy of his results for use as a guide in refining and upgrading the products at the laboratory.



Diagnostic antiserum for laboratory detection and identification of fish disease agents is prepared in rabbits. Demonstrated here is a subcutaneous method of infection used to stimulate potent response by the rabbit. (Photo by H. M. Stuckey)

Whirling disease in trout.—This serious infection, which cripples and kills young salmonids, is caused by a single-celled spore-forming protozoan accidentally introduced into eastern North America from Europe about 20 years ago. The parasite is now well established in the East, in the Midwest, and in Nevada. To avoid further spread of the organism, fish culturists must recognize and destroy infected stocks of fish and disinfect contaminated waters that are to be used for raising trout. Demonstration of the spores is the most reliable method of diagnosing the disease or detecting infection.

Two diagnostic methods are available for releasing and concentrating spores; one involves a sequence of enzyme digestions and the other the recovery of spores in a plankton centrifuge. In tests of the two methods, 31% more spores were recovered by enzyme digestion than by centrifugation.

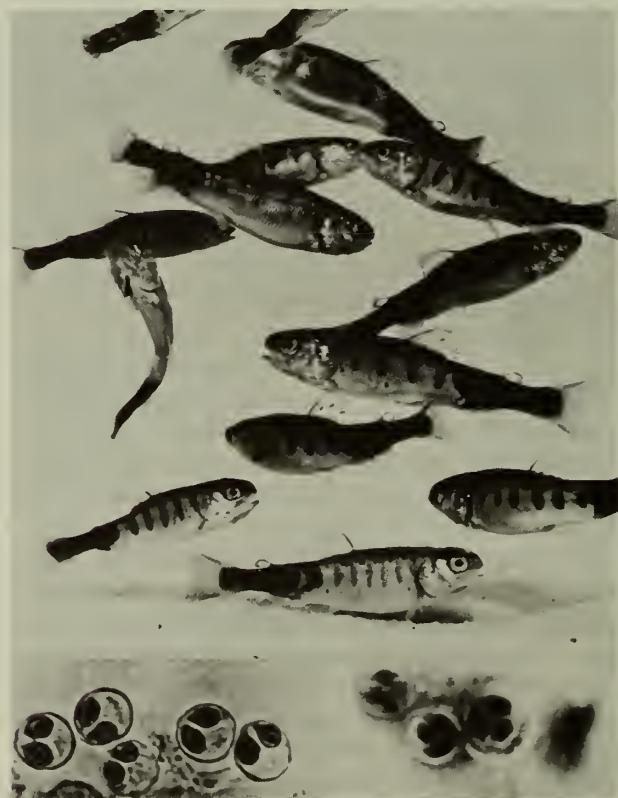
Although demonstration of the spores is the most reliable diagnostic tool, whirling disease develops so slowly that several months are necessary for spores to form. At the Eastern Fish Disease Laboratory, definitive serological methods are being developed to detect the infection before spore formation, to identify the still unknown infective stage, and to insure correct diagnosis.

One serological method for identifying the causative protozoan involves the use of prespore stages of the organism in preparing rabbit antiserum. In an immunodiffusion test, the antiserum reacted with the organism to form a visible band within 24 hours.

As in the culture of fish viruses, intermediate developmental stages of the protozoan have been matured to spores in culture medium. The cultured spores have been functional and provide a promising approach to identifying the life stage which infects fish.

Kidney disease of salmon and trout.—Bacterial kidney disease is a chronic infection of salmon and trout which causes widespread mortality in fish of all ages. Because the disease cannot be treated effectively with antimicrobial drugs, practical control can best be achieved by recognizing the sources of infection and propagating healthy stock. Control requires sensitive detection methods. The serological precipitin test is a specific diagnostic tool for identifying the disease, but it is not sufficiently sensitive for detection of lightly infected animals during early incubation.

Fluorescent antibody techniques (FAT), which are among the most sensitive serological tests, involve fluorescent dyes which are coupled to a specific antiserum. Bacteria are targets for the specific antiserum and because of the fluorescent dye, microorganisms are brill-



Rainbow trout showing the typical "black-tail" sign of whirling disease. At lower left is a group of five microscopic spores which cause the disease. At lower right is a group of three spores which have been grown in test tube culture. (Photo by H. M. Stuckey)



Kidney disease bacteria (of salmon and trout) treated with a specific antiserum bound to a fluorescent dye. Viewed after this treatment with a microscope under ultraviolet light, the disease agent can be positively identified at concentrations 500 to 1,000 times lower than those at which it can be detected by ordinary staining methods. (Photo by H. M. Stuckey)

liant when viewed with a microscope under ultraviolet light. At the Eastern Fish Disease Laboratory, biologists developed a highly successful FAT that not only identifies the bacterium but markedly increases the sensitivity of detection.

To measure the increase in sensitivity, the biologists prepared parallel test specimens (from natural outbreaks) for study by FAT and by gram staining. The FAT revealed a significantly greater number of infections. The increase in sensitivity was quantified by diluting infected tissue homogenates and ascertaining the greatest dilution at which the causative organism could still be found. The FAT proved to be 500 to 1,000 times more sensitive than the gram stain—the previous standard method of bacteriological examination for kidney disease. The technique thus greatly improves the probability of early field recognition of this problem infection.

Attenuation of the virus of infectious pancreatic necrosis.—Vaccines are widely used in human and veterinary medicine as one of the most effective methods of preventing disease. Live but attenuated virus, as typified by the well-known Sabin polio vaccine, has decided advantages. However, thus far no one has been able to attenuate the virus of the most common fish viral disease, infectious pancreatic necrosis (IPN), for use as a vaccine.

Biologists at the Eastern Fish Disease Laboratory are using cell cultures from lampreys, high and low temperature incubation in nonsusceptible fish cell cultures, and massive inoculation of cell cultures as new approaches toward attenuating IPN virus. Unfortunately, early tests on fish have shown that several derived strains of virus lack overt virulence for fish—a fundamental requirement for a practical vaccine.

Fish Control Laboratory

Quinaldine sulfate as an anesthetic for fish.—Quinaldine sulfate was shown to be an effective chemical for use in calming or anesthetizing fish and making them easier to handle in fish cultural operations. When the anesthetic was added to water in which channel catfish were held, the fish rapidly eliminated the drug in their urine. When the drug was injected intraperitoneally, however, excretion in the urine accounted for little of the drug; more than 70% of the injected dose was eliminated across the gills. Although not all of the drug could be accounted for, no detectable residues could be measured in the bile, plasma, or urine 24 hours after injection. When channel catfish were exposed to 65 mg/l of quinaldine sulfate for 30 minutes and transferred to fresh flowing water, residues could be detected in only the first of four samples collected at intervals of 1, 2, 4, and 14 days.

Indications of sedation with quinaldine sulfate are not well defined because fish quickly lose vertical orientation without exhibiting progressive stages. Therefore, observations of increased opercular ventilation rates, decreased sensitivity to visual stimuli, and random surface swimming were used as criteria of sedation. Test concentrations were 1, 5, and 15 mg/l quinaldine sulfate. Toxicity data indicated that concentrations of 15 mg/l or more were lethal to 11 of 12 fish species tested.

Rainbow trout were held successfully under sedation at 1 and 5 mg/l quinaldine sulfate (powder) in waters of various hardness for 4 days at 17° C. At 15 mg/l, however, only one fish survived the prolonged exposure. Fish that lost equilibrium, but did not die, recovered in less than 3 minutes when they were transferred to untreated water. A few fish lost equilibrium early in exposure but then recovered within 1.5 hours.

Oxygen consumption of rainbow trout with and without sedative doses of quinaldine sulfate was measured in open vessels. Nine 5-g fish were placed in each 3-liter container of well water and were monitored for rate of oxygen uptake with an oxygen electrode. Sedated fish were visually quieter and showed a 22-40% decrease in oxygen uptake.

Selective toxicants.—Renovation of lakes and streams with toxicants generally removes the entire resident population, even though the target animals are usually of a single species. The carp is a common coarse fish for which fish toxicants are applied. Screening tests at the Fish Control Laboratory have identified an experimental compound known only as GD-174 that is uniquely selective against carp. When four samples of GD-174, each containing different ratios of its three isomers, were tested against carp and green sunfish simultaneously, carp were 19-26 times more sensitive than the sunfish.

Collecting aids.—Management techniques to improve recreational fishing frequently include reclamation of lakes or streams by destroying the entire existing fish population and replacing it with more desirable stocks. It is sometimes desirable, however, to salvage large predators of desirable species to use for restocking or as brood fish. Thanite is a compound which causes fish to surface in a comatose condition. The affected fish revive if they are transferred to clean, aerated water.

Field tests were conducted in six ponds (0.75-3.21 acres in size) in Alabama and Georgia. The percentages recovered of the catchable sizes of each fish species present were as follows: largemouth bass, 75.2; bluegill, 82.3; and redear sunfish, 67.1. Survival of collected fish placed in tanks of fresh, aerated water was excellent.

Subsequent experiments were conducted in four drainable, 0.1-acre experimental ponds to evaluate the effects of Thanite on selected species of fish. Largemouth bass, bluegills, green sunfish, rainbow trout, goldfish, golden shiners, blue catfish, and channel catfish were stocked. Total recoveries of fish (all species combined) among ponds ranged from 79.5 to 94.1%. By species, overall recoveries were highest for blue catfish (97.9%) and largemouth bass (93.9%) and poorest for golden shiners (70.5%) and goldfish (64.5%). No mortalities occurred among fish that were transferred to holding tanks and allowed 2 days to recover before further handling, but 3-8% mortalities occurred among fish handled on the day after collection.

A field trial was conducted in a 2-acre pond near West Salem, Wis., to evaluate the efficacy of Thanite in northern waters at low temperatures. The pond contained a natural population of bluegills and black bullheads, and three species—marked largemouth bass, chinook salmon, and channel catfish—were added 2 months before the Thanite treatment. The pond was treated with 1.5 µg/l of Thanite in late October (temperature, 15° C). Fish began surfacing within 30 minutes after treatment and were collected over a period of 5.5 hours. They were easily captured with dip nets and transferred to holding tanks on shore. Of the first 100 pounds of bluegills collected, 94% revived in the holding tank. Fish were then

hauled to the Fish Control Laboratory and held for assessment of survival. Even after the severe stress of being crowded in holding tanks and being handled 3 times in the capture and hauling process, 50% of the captured salmon, 58% of the largemouth bass, and 69% of the bluegills survived for at least 5 days. Black bullheads and channel catfish were not vulnerable to capture after exposure to Thanite.

To date, 73 species of fish, including representatives of 14 families, have been collected alive, but consistently good results in capturing catfishes have not been achieved.

In residue studies over a 28-day period, no Thanite was detectable in pond water after 7 days and none in the mud after 14 days.

Because Thanite deactivates slowly in water, attempts were made to identify oxidizing or reducing agents that might speed the degradation. Several chemical deactivators were tested. These included two oxidizing agents, KMnO₄ at 1 mg/l and chlorine at 0.5 mg/l, and a reducing agent, sodium thiosulfate at 10 mg/l. Although the rate of deactivation increased slightly after the addition of the chemical agents, none of them showed significant potential as a practical detoxifier for Thanite.

Counteraction of fishery chemicals.—Increasing concerns over the discharge of chemicals into lakes and streams have led to research in the counteraction or removal of compounds used to manage or treat fish. Chemicals can be removed from treated water, or their toxicity can be counteracted with oxidizing agents, reducing agents, or light, or by metabolism by aquatic organisms.

Filtration through activated charcoal (carbon) effectively removed seven of eight chemicals tested. Only formalin could not be removed. Potassium permanganate and chlorine were less versatile but oxidized antimycin, quinaldine sulfate:MS-222, rotenone, and malachite green to nontoxic forms. Sodium thiosulfate, a reducing agent, proved ineffective. Ultraviolet light degraded antimycin, and microbial action degraded TFM.

In laboratory tests, activated charcoal effectively removed Furanace from treated water passed through a miniature column containing 35.5 g of carbon. The column was redesigned in a prototype filter to accommodate removal of Furanace from raceway quantities of water. About 100 pounds of 20-× 40-mesh granular activated charcoal were placed in the filter apparatus. Treated water was pumped through the filter at a rate of 50 gallons per minute. The filter apparatus effectively removed 1.0 mg/l of Furanace from well water at La Crosse, Wis., and from trout production raceways at the Fish Cultural Developmental Center, Bozeman, Mont. Techniques were developed for the removal of Furanace from water after static treatments and flow-through treatments of the race-



An experimental carbon filter system was effective for removing Furanace, a bactericide, from treated waters in trout raceways at the Fish Cultural Development Center, Bozeman, Mont. (Photo by L. L. Marking)

ways containing production loads of rainbow trout, without interference in hatchery operations.

The breakthrough point of Furanace for the filter also was determined during the cooperative study at Bozeman; 95,000 gallons of treated water were pumped through the filter before Furanace appeared in the filter effluent.

Toxicity of antimycin to nontarget organisms.—Freshwater clams have been reported to be especially sensitive to the fish toxicant, antimycin. At the Southeastern Fish Control Laboratory, three species of clams (*Corbicula* sp., *Elliptio* sp., and *Magnonasias boykiniana*) were exposed to various concentrations of antimycin for selected time periods and in selected water hardnesses. The organisms were then transferred to fresh water, and mortality was assessed after 28, 42, and 56 days. *Corbicula* was highly resistant to antimycin in all water characteristics examined. A definite response by *Elliptio* could not be determined because mortality in the controls

was equal to or greater than that in animals exposed to antimycin. This mortality may reflect stresses due to handling. *Magnonasias* exposed to concentrations of antimycin at 2 and 5 $\mu\text{g/l}$ for 12 hours and to 50 $\mu\text{g/l}$ for 24 hours showed an increased mortality over controls at 28, 42, and 56 days. Even so, no more than 31% of the animals treated for 24 hours with 50 $\mu\text{g/l}$ died. Although *Magnonasias* thus was somewhat sensitive to antimycin, it is not likely that populations of this species will suffer permanent damage if present in treated areas.

Long-term impact of antimycin treatments.—The effects of many antimycin treatments have been thoroughly documented during the immediate period of treatment, but long-term effects on the ecosystem have seldom been assessed. In a 1-year study of an antimycin-treated pond at Max McGraw Wildlife Foundation, transient changes related to the toxicant were seen in plankton and benthos populations, but not in the oxygen concentration.

Although some benthic organisms and plankters are sensitive to antimycin at fish-killing concentrations,



The identification and testing of nontarget food organisms is an integral part of research on the development of safe and effective fish toxicants. (Photo by L. L. Marking)



Drawing blood from a caudal peduncle of a fish is usually a new experience for a student technician. Watching is a first step in learning.
(Photo by L. L. Marking)

impact on the community does not extend beyond 1 year. In the present study, numbers and species increased as a result of antimycin treatments. Rainbow trout stocked shortly after the antimycin treatment found abundant food organisms and grew at a rate comparable to that of trout in other similar waters.

Sea Branch Creek (in Wisconsin) was treated with antimycin in the fall of 1972 to remove rough fish, which competed with trout in the stream. A contract study was conducted by the University of Wisconsin-Stevens Point on invertebrate populations before and after an unintentional overdose treatment. A thorough analysis of the chemical application revealed that the concentrations of antimycin at many points in the stream were 4 times as high as recommended, primarily due to miscalculation. Although the excessive dosage had severe adverse effects on the biota, the effects were temporary. Species diversity and total biomass returned within 18 months to levels equal to or greater than those before treatment.

Degradation of antimycin.—A study was conducted to determine the hydrolysis of ^{14}C -antimycin in well water buffered to pH 5, 7, and 9, and in pond water (pH 8.7). Antimycin was hydrolyzed slowly in solutions buffered at pH 5 or 7 but decreased by 61% in 1 day and by 74% in 2 days in the solution buffered at pH 9. Thereafter, there was little or no degradation.

Uptake and turnover of antimycin in fish.—In a study of the uptake and distribution of antimycin in fish, brown bullheads held in fiber glass tanks were exposed to $45\mu\text{g/l}$ of ^{14}C -antimycin for up to 48 hours. Three fish were removed after each of four periods of exposure: 12, 24, 36, and 48 hours. The blood, brain, gill arches, liver, kidney, and bile were analyzed for radioactivity. Radioactivity was highest in the bile and lowest in the blood at all sampling periods. The concentration of radioactive material decreased in brain and gill tissue during the 48-hour period but fluctuated throughout the experiment in bile, liver, and kidney.

The elimination of ^{14}C -antimycin was studied in brown bullheads exposed to 45 $\mu\text{g/l}$ of ^{14}C -antimycin for 48 hours and then transferred to fresh water. Organs and tissues were analyzed, as in the study described above, to a maximum interval of 96 hours. The amounts of ^{14}C materials in tissues and bile gradually declined with the lapse of time after the fish were placed in fresh water. The level of antimycin decreased by about 50% in both muscle and offal after the 96-hour withdrawal period, indicating metabolism or excretion, or both, of the parent compound. The level of ^{14}C degradation products had decreased by about 40% over the same period, indicating a similar path of elimination for these compounds.

Fish Farming Experimental Station

Polyculture in raceways and tanks.—To determine whether tilapia and buffalofish affect the growth of channel catfish in connected raceways, Fish Farming Experimental Station biologists stocked two raceways, each with four compartments (a, b, c, d), with: (a) channel catfish, (b) tilapia, (c) bigmouth X black buffalo hybrids, and (d) channel catfish. Compartments of two control raceways contained (a) channel catfish, (b and c) no fish, and (d) channel catfish. The primary objective of the test was to determine the effect of tilapia and buffalo on water quality or growth of fish in compartment d, the farthest downstream compartment to receive water that originated in compartment a. Catfish received pelleted feed, but the tilapia and buffalo were not fed.

The presence of tilapia and buffalo did not significantly affect either water quality or growth of catfish in compartment d. Total food use was better in the raceways containing tilapia and buffalo, however, because the production of these fish was a bonus. Tilapia and buffalo consumed a wide variety of microscopic plants and animals. Tilapia kept the sides and bottom of their compartments free of algae and debris.

Production of monosex grass carp.—Introduction of grass carp into the United States has generated controversy due to uncertainty about the effects of this species on native fish and wildlife. Resolution of the question has been slowed by the reluctance of biologists to release this exotic species in vulnerable situations without safeguards against naturalization. Grass carp that will not reproduce are needed.

Hybridization, androgenesis, gynogenesis, and sex reversal were studied for production of monosex or sterile fish. Gynogenesis apparently holds the most promise. It was achieved in eggs fertilized with sperm that had been irradiated with ultraviolet light, a technique that excludes paternal influence from inheritance and yields only female progeny. Gynogenesis seems feasible and practi-

cal; more than 30,000 monosex grass carp were produced during the year.

Androgenesis is a rare phenomenon in which eggs are fertilized by two spermatozoa and female chromosomes are lost. Thus the all-male offspring contain two sets of chromosomes derived from separate spermatozoa.

Hybridization is a potential method for producing sterile fish with weed-control efficacy. Since grass carp have 48 chromosomes and carp have 100, the formation of egg and sperm in a hybrid should be impossible because maternal and paternal chromosomes will not pair. However, most of the hybrids died and the survivors were fertile, suggesting that diploid fish die and that the few survivors are polyploid and have the capacity to reproduce.

Sex reversal is potentially the most economical way to produce monosex fish. A few sex-reversed males produced from hormone-fed gynogenetic females could sire millions of monosex female progeny, and costs would be comparable with those of producing normal offspring by usual hatchery techniques. Effectiveness of this technique will be evaluated in spring 1976, when the results of experiments now under way become known.

Electrical current for controlling fish in ponds.—Intensive laboratory and field studies on electrically shocked channel catfish indicate that the usefulness of electrical stimuli for harvesting channel catfish is severely limited and consequently cannot be recommended.

A series of tests at the Fish Farming Experimental Station demonstrated four significant limitations: (1) less than 50% of the fish in a pond were recoverable when electrically shocked; (2) no single frequency or voltage was equally effective for fish of all sizes; (3) tissue damage occurred when voltage amplitudes were 0.8 and 1.6 volts per centimeter, with the three electrical waveforms tested; and (4) the recovery time and survival of fish was directly proportional to the strength of the shock and to the length of time that the fish were treated.

In a separate test, channel catfish learned to avoid an electrical field (pulsating exponential-wave direct current of 1 millisecond duration; frequency, 24 pulses per second; amplitude, 0.01 volt per centimeter). Doubling the conditioning period did not significantly increase retention of a learned response.

Technique for marking catfish.—Identification of individual fish is important in selective breeding studies, as well as in other phases of fishery research and management. Ideally, identification techniques should be inexpensive and permit a great variety of marks; the marks should be relatively permanent, should not affect behavior and feeding, and should be easy to apply. Such methods of marking as the use of dyes, "cold" branding, "heat" branding, tagging, and fin clipping have not been

fully dependable for channel catfish, and often the marks are lost within a few weeks.

Channel catfish branded with silver nitrate at the Fish Farming Experimental Station were still distinguishable after more than 1 year, and long-term retention appeared assured. Thus it appears that a practical and dependable method has been developed for identifying individual catfish.

Characteristics of discharged aquacultural waste water.—Guidelines for limitations on settleable solids in water discharges have been recommended by the Environmental Protection Agency. Settleable solids are defined as the volume of solids that settle within 1 hour under quiescent conditions in an Imhoff Cone. For pond culturing systems, the recommended maximum instantaneous concentration is 3.3 ml/l.

Measurements were made of effluents from 0.25-acre ponds that had been filled for periods of 48 hours to more than 1 year. Seven ponds contained no fish and one contained about 250 pounds of fish.

Of a total of 136 samples collected, 86% were within the recommended effluent limitation. In none of the ponds did the amount of settleable solids exceed 3.0 ml/l after 1,700 gallons of water had been discharged, which usually occurred within the first 5 minutes of draining. Thus it appears that the limitations on settleable solids recommended by the Environmental Protection Agency will impose no serious limitation on typical warmwater fish farming operations.

Effects of aeration on channel catfish production.—The problem of increasing production in raceways and other fish-rearing facilities is under continuous investigation. Normally, production is limited by the oxygen content of the water and the presence of waste metabolites. Increased aeration and water exchange offset the effects of fish density, but excessive aeration and water exchange are expensive and nonproductive. At the Fish Farming Experimental Station, tests were conducted to provide more definitive values for needed aeration and water exchange.

Circular tanks, 1 m³ in capacity, were each stocked with 800 channel catfish fingerlings (average weight 51 g). Four conditions of aeration and flow rate were tested. A low flow that gave a water exchange time of 14.7 minutes was divided among four tanks, two of which received supplemental aeration (the other two did not). A higher flow that gave a water exchange time of 8 minutes was also similarly divided into aerated and nonaerated tanks.

In tanks receiving a low flow and no aeration, dissolved oxygen was lower than in the other test tanks, the fish grew more slowly, and feed conversion efficiency was poorer. In the tanks with the higher rate of flow, the

concentration of dissolved oxygen was higher, but varied somewhat from one test condition to another. Growth and feed conversion efficiency were not affected. Survival was not significantly affected under any of the test conditions included in the experiment. The results of this experiment indicated that once sufficient water exchange or aeration was provided to ensure a safe minimum level of dissolved oxygen (about 3 mg/l), additional water flow or aeration (and consequently increased dissolved oxygen) did not improve fish growth, food conversion efficiency, or survival.

Fish Genetics Laboratory

Genetics of wild and hatchery strains of rainbow trout.—Significant departures from typical concepts of adequate breeding designs for heritability and genetic correlation estimations have been defined; as a result, experiments have been considerably enlarged. Thus meaningfulness of most published results on fish heritability must be viewed with extreme skepticism because the experiments have been inadequate.

Some 40 heritability estimates have been obtained which vary considerably for the same attribute in different strains of trout. Testing of noncaptive survival in two strains of trout has revealed significant differences. In both strains, survival rate was directly dependent on size of fingerlings at release. Fish heavier than 25 g at release were not selected against as heavily as were fish of smaller size, and the larger fish tended to have the faster growth after release. These differences should be taken into account when size at release is determined for fish from Federal hatcheries.

Three effects of 25% inbreeding have been experimentally demonstrated: (1) hatching success was unchanged; (2) fry mortality increased 19% over that of controls during a period of 120 days posthatching; and (3) weight after 120 days was depressed by 11% in the inbred fish. Since 25% inbreeding is likely to be equalled or exceeded at many hatcheries, breeding schemes have been formulated that should reduce these problems.

Protein gene analysis has revealed variants in 11 of 15 systems examined. The frequency of variants differs significantly among strains. The Fish Genetics Laboratory has the capacity to obtain 200 measurements daily for each of four enzymes or other proteins.

Computerization of data collection and analysis.—An "assembly line" approach to handling of data has been completed at the Fish Genetics Laboratory. In addition to all new data, a backlog of data from previous years of operation of the Laboratory has been reduced to punched-card entries. The flow of data is as follows: (1)

Data are collected by the fish-cultural section and recorded on a lot record maintained for each lot (family) of fish. This single record contains all data originating from the fish-cultural operation during the entire life cycle of a specific lot of fish. (2) Data from each lot are transferred to punched data cards from the lot record at three ages (postfertilization) during the first year of life: 42 days (swim-up stage), 147 days, and 364 days. Thereafter data are converted to card form after the fish have spawned at 2, 3, and 4 years of age. (3) Data on biochemical genetics, morphology, and field tests are converted to card form at the completion of each phase of collection. (4) After all lots in a specific program have completed a phase, the data are summarized and heritability is estimated on each appropriate trait. Data from the strain evaluation program are also subjected to mass correlation search for associations between traits. (5) Data cards are held at this point to await further analysis at the completion of the individual program. About 50 heritability and genetic correlation estimates will result from each strain evaluated. All samples except those from raceway tests will yield heritability and genetic correlation estimates.

Mortality and growth of formalin-tolerant rainbow trout.—Formalin-tolerant trout from the Fish Genetics Laboratory were compared with rainbow trout from Ennis, Mont., at McNenny National Fish Hatchery; during December and January each year, this hatchery has a recurrent *Gyrodactylus* problem that is remedied by formalin treatment. Typically, significant numbers of trout are lost during treatment. During the one test, no formalin-tolerant fish died, whereas 12% of the Ennis trout were lost.

Growth of four selected groups of rainbow trout held under hatchery conditions were compared at the Fish Cultural Development Center, Bozeman, Mont. These groups and their length increases in inches after 17 months were as follows: accelerated growth, 8.5; standard line, 7.8; slow growth, 6.0; and formalin tolerant, 7.4. Since environmental conditions at that station are unlike those at the Fish Genetics Laboratory, the tests will permit comparisons of environmental influence on growth. Additionally, 1,000 fish from each of the groups were planted in water of the Crow Indian Reservation for further observation of survival and growth.

Southeastern Fish Cultural Laboratory

Protein and lipid requirements of largemouth bass.—Growth and survival of largemouth bass fingerlings were compared among groups receiving 38-54.5% protein (casein) and 0-6% salmon oil supplementing 6% corn oil in diets fed at the rate of 5% (dry basis) of body weight per

day. No differences in growth and survival occurred among the different groups. Supplemental linolenic acid apparently is not essential, as it appears to be in diets for salmonids and striped bass. These results may be used as a preliminary guide in formulating practical largemouth bass rations with other sources of protein.

Largemouth bass fingerlings can be maintained at relatively dense stocking rates in circular tanks with acceptable growth and survival. Stocking rates of one, two, and three fish per 8 gallons of water yielded weight gains after 91 days of 625, 588, and 593% and survival rates of 98, 93, and 92%, respectively. This method of production compared favorably with hatchery pond production.

Alpha-cellulose for dispersal of quinaldine.—Quinaldine is an effective anesthetic for fish, but it is immiscible in water and difficult to apply. Its acid sulfate salt dissolves readily but lowers the pH of water, becomes mostly ionized, and is taken up across the gills too slowly to be very effective. Alpha-cellulose, however, may be used as a carrier to disperse free quinaldine. A mixture of 4 parts alpha-cellulose and 1 part quinaldine may be pre-weighed, conveniently transported, and applied to water as a homogeneous moist powder.

A counter-current heat exchanger for temperature control.—Rearing aquatic organisms in tanks usually requires a continuous flow of fresh water above or below ambient temperature. A simple counter-current heat exchanger was used to thermally "isolate" flowing tank water; heat passes from inflow water to discharge water in a system below ambient temperature and from discharge water to inflow water in a system above ambient temperature. A prototype system in which water temperature was decreased from 18° to 9° C was 50% efficient. Refinements can produce greater efficiency that should reduce heating or chilling costs for flow-through systems by more than 50%.

Tunison Laboratory of Fish Nutrition

Soybean meal as a substitute for fish meal in salmonid diets.—Study of the feasibility of substituting plant protein for expensive and hard-to-get fish meal in the diets of trout and salmon was continued at the Hagerman, Idaho, Field Station. Rainbow trout showed normal growth and development when fed diets containing high levels of laboratory processed soybean meal. General appearance and color were those of normal hatchery reared trout. In 1 year the average weight of the fish increased from 0.02 to 12.0 ounces and the average length from about 1 to 12 inches. A taste panel was unable to detect a difference between the fish fed soybean oil and those fed commercial diets.

Coho salmon did not thrive on the all-plant protein diets that were satisfactory for rainbow trout. However, only 20% fish meal was needed in "starter" diets and not more than 10% fish meal in "grower" diets for coho salmon if the rest of the protein was supplied by properly processed soybean meal.

These feeding trials again pointed out the critical nature of the heating process if soybeans are to be successfully used in salmon diets. In attempts to find processing methods which are compatible with large-scale production, fish culturists found steam cooking to be about equal to dry roasting. In steam cooking, as in dry roasting, the time and temperature of heating are very critical.

Treatment of hatchery water for reuse.—An experimental culture system with 100% water reuse was developed to meet the need for complete treatment of hatchery wastes. In this system, a baffle-plate settler removed solids; a gravel-substrate nitrifying filter removed ammonia; an activated carbon substrate denitrifying filter removed nitrate; and a combination ozone-contactor and froth skimmer removed residual soluble and suspended solids. A sodium bicarbonate and calcium chloride buffer-nutrient controlled pH by producing 1% salinity and facilitated ammonia removal by providing inorganic carbon that promoted growth of nitrifying bacteria. Brown trout stocked at high density grew rapidly in clear, 100% reused water that was free of odor and taste. A practical system is being constructed that will enable fish culturists to use these advanced water treatment techniques.

Nutritional cataracts in trout.—Substitution of whitefish meal for herring meal in trout diets used in Federal hatcheries has caused a high incidence of lens cataracts in various species of trout. At the Tunison Laboratory, therefore, the properties of the two meals were investigated in a practical diet for rainbow trout fry. The results confirmed previous observations: fry fed diets containing whitefish meal grew slowly and the incidence of cataracts was 75%; fry fed diets containing herring meal grew normally and developed no cataracts. The study showed, further, that the addition of mineral ash obtained from herring meal to the diet containing whitefish meal improved growth and markedly reduced the incidence of cataracts. Whitefish meal is thus a potentially good source of protein in trout diets when supplemented with key minerals.

Effects of artificial substrates on trout incubation.—The increased growth rate and survival of Atlantic salmon fry incubated on artificial substrate prompted an investigation of the effect of substrate and loading density on growth and survival of brook trout. Brook trout eggs were incubated in drums, with and without an artificial substrate, at densities of 1,500 and 3,000 eggs per drum.

Neither substrate nor loading density produced significant effects. However, the mean weight of brook trout hatched and reared in drums was significantly greater than that of trout reared in jars and circular tanks.

Nutrition and food related cataracts.—Lens cataract, an opaque clouding of the lens of the eye, continues to be a serious problem in hatchery reared trout. Retarded growth, poor food conversion, and increased mortality in the hatchery, as well as lowered survival of stocked fish, can result from this condition. Studies at the Tunison Laboratory have indicated that several nutritional factors are involved in cataract formation. Ophthalmoscopic (biomicroscopic) and histological characterizations of various developmental phases of cataracts have been made. Information of this type may play a significant role in diagnosing and eliminating cataracts in hatchery propagated fish.

Western Fish Disease Laboratory

Effect of hooking stress on fish.—Although increased fishing pressure is leading to the establishment of more catch-and-release management programs, little information is available on the physiological impact of such practices on the health of the affected fish populations. In a joint project, personnel of the Western Fish Disease Laboratory and the Utah Cooperative Fishery Research Unit estimated the severity of hooking stress (fish were played 0-5 minutes) and the time needed for recovery (0-4 days) for brook, brown, and cutthroat trout; arctic grayling; and largemouth bass. Blood chemistry disturbances were more severe and lasted longer in arctic grayling than in the other species. In all species tested, the full physiological impact of hooking stress was delayed for several hours after hooking, showing that the apparently good condition of a fish immediately after release can be misleading.

Resistance to stress as a characteristic of rainbow trout strains.—Improving overall fish health through selective breeding for physiological superiority, as well as for large size and rapid growth rate, is an approach that has received little attention in the past. In a cooperative project, researchers at the Western Fish Disease Laboratory and the Fish-Genetics Laboratory developed a promising technique for characterizing rainbow trout strains: measuring physiological competence to closely regulate and control blood chemistry fluctuation. Results to date indicate that certain strains have superior ability to regulate blood glucose, chloride, and calcium levels, which are important in resistance to stress and disease and are measurable genetic markers.

Techniques for field diagnosis of virus diseases.—Fishery managers need methods for quick and accurate identification of diseases in the field. Biologists at the Western Fish Disease Laboratory have studied the feasibility of using peripheral blood smears and anterior kidney imprints for fast, relatively simple, reliable, presumptive, in-the-field diagnosis of infectious hematopoietic necrosis. Abnormal changes most frequently seen in the peripheral blood smears and anterior kidney imprints are: (1) necrotic blood cells, (2) monocytes with varying degrees of foamy appearance, and (3) bilobed red blood cells. Recent studies have shown that similar changes occur in fish infected with the viruses causing infectious pancreatic necrosis and viral hemorrhagic septicemia. Thus this hematological technique can apparently be used for in-the-field diagnosis of all three virus diseases. Since viral hemorrhagic septicemia is unreported in the United States, this technique and a good case history of the fish involved are usually helpful in determining which of the other two viruses has infected a particular lot of fish. The presumptive diagnosis should be confirmed, however, by virological and serological tests and histological examination.

Improvement of fish cultural methods.—Environmental factors and fish cultural practices profoundly affect the physiology of propagated fishes and hence their overall health. Water chemistry, temperature fluctuations, and other environmental factors, as well as crowding and handling and fish disease therapeutants, impose stress and thus endanger fish health. The threat of excessive stress is inherent in the concept of intensive fish culture. To bring together the existing information in this field and make it more readily available to fishery managers, a draft of a textbook, "Environmental factors in fish diseases," was prepared at the Western Fish Disease Laboratory.

Bacterial gill disease, frequently a sign of crowding stress, is one of the most common and troublesome fish diseases. Data are needed on its physiological implications in intensive fish culture so that densities which begin to impose stress on salmonid populations can be determined and optimum fish health maintained.

The density of juvenile rainbow trout and coho salmon was increased from 0.5 pound per cubic foot of water—the population density to which the fish were adapted—to 1-12 pounds per cubic foot, while a constant water flow of 1 gallon of water per minute per pound of fish was maintained. Relatively severe blood chemistry disturbances occurred immediately in the salmon held at densities of 6 and 12 pounds per cubic foot of water, and persisted for about 1 week. Blood chemistry regulation remained essentially normal, however, in salmon held at densities up to 2 pounds per cubic foot, indicating that little stress was being imposed on salmon held at these

density levels. The rainbow trout were much less affected by crowding and handling stress. The density at which disturbances in blood chemistry regulation begin to compromise resistance to bacterial gill disease in this species remains to be determined.

Improved methods of disease control are an important part of the ongoing effort to increase the efficiency of intensive fish culture. In addition, hatchery effluent treatment may be necessary to meet water quality standards imposed by regulatory agencies. To meet these standards, biologists at the Western Fish Disease Laboratory are testing ozone in the laboratory to determine dose and contact time required for the inactivation of bacteria and viruses pathogenic to fish.

Under controlled conditions, a 2-minute contact with 0.01 ppm residual ozone should completely inactivate the causative organism of furunculosis and enteric redmouth disease in hatcheries supplied with soft water. Ozone disinfection differs from chlorine disinfection in that an ozone residual cannot always be attained in some waters; however, this difference apparently does not diminish its disinfecting ability.

Establishment of immunity by vaccination.—A promising method of reducing fish mortality is the development of vaccines to control specific diseases. In a cooperative study, personnel of Wildlife Vaccines, Inc. and the Western Fish Disease Laboratory developed and tested a vaccine and vaccine delivery system. The delivery system involves the placement of fish in a vacuum chamber with a vaccine in a hyperosmotic solution. Air pressure is reduced to 230 mm Hg, quickly restored to normal atmospheric pressure (760 mm Hg), and the cycle is repeated a total of three times. These changes in pressure, coupled



Infiltrator system used to immunize fish by vacuum infiltration.
(Western Fish Disease Laboratory photo)

with the hyperosmotic solution, force the vaccine into the fish. The process takes 2 minutes. This technique has four obvious advantages: (1) large numbers of fish can be immunized at one time; (2) there is practically no limit on the size of fish that can be treated; (3) relatively small volumes of vaccine are needed; and (4) multiple vaccines can be administered simultaneously. The system is referred to as "vacuum infiltration and forced fluid influx."

Vaccines have been tested under laboratory conditions for the virus of infectious hematopoietic necrosis, and the virus of enteric redmouth disease. In all cases, the vaccination of fish against these diseases resulted in significant protection when the fish were challenged with live virulent organisms. The procedure gives protection from disease equal to or better than that obtained by the standard method of injection. The commercial development of fish vaccines appears favorable.

Western Fish Nutrition Laboratory

Effects of three forms of vitamin C in rainbow trout diets.—Different lots of rainbow trout were raised to 60 g in weight on test diets containing L-ascorbic acid (C_1), calcium ascorbate-2-sulfate (C_2), or iso-ascorbic acid (iso- C_1) as the vitamin C component. Maintenance of normal growth required 10 times as much iso-C in the diet as of either C_1 or C_2 (equimolar quantities). After fish reached 60 g in weight, representative random samples of 100 fish from each diet treatment lot were placed on a diet containing no vitamin C until symptoms of scurvy appeared. Scurvy first appeared after 60 days in fish previously fed iso- C_1 as the sole source of vitamin C in the diet. After 150 days on the deficient diet, 40% of the fish in this lot showed acute scurvy symptoms, whereas fish previously fed either C_1 or C_2 continued to grow normally, exceeded 250 g in average weight, and showed no scurvy symptoms. Thus iso- C_1 , which is commonly used in the food industry to preserve food and prevent oxidation, supported growth in young rainbow trout, but the amount of C-active material stored was much lower than that in fish whose diets contained either C_1 or C_2 as the vitamin C component. Vitamin C_2 , now available in several chemically stable forms, has distinct advantages over the very labile forms of C_1 currently used in fish feed. An economical form, calcium ascorbate-2-sulfate, was crystallized and tested favorably as the sole source of vitamin C for young rainbow trout. The role of these compounds in disease resistance in fish has not been thoroughly investigated. The synthesis, biological testing, and chemical analysis of intermediate and end products of metabolism were part of a cooperative effort between the personnel of the Letterman Army Institute of Research, the University of Colorado, and the Western Fish Nutrition Laboratory.

Amino acids in fish feeds.—Amino acid patterns of diet ingredients have been assembled, and many potential ingredients have been analyzed for amino acid content. Results have been incorporated into the international data bank of nutrient components in feed ingredients. Several exotic types of grasses have been analyzed, together with crab waste, fly larvae, algae, and cereal grain products. The effect of processing on amino acid content was assayed by comparing components in finished feeds with those in feces, urine, and gill wastes from test animals fed these components under standard test conditions. Remodeling of the amino acid analyzer has made possible the rapid analysis of amino acids in feeds, feed ingredients, and physiological fluids.

Fish blood clotting mechanisms.—Blood coagulation intermediates were prepared for the National Institute of Health (NIH). Lamprey plasma was prepared and shipped to NIH in a cooperative effort between the staffs of NIH and Western Fish Nutrition Laboratory to determine the mode of action of fibrinogen-to-fibrin reactions in one of the lowest vertebrates. Previous work has disclosed a common method for the formulation of intermediates in the soft, then cross-linked hard, clot of salmon blood and human blood plasma components. Scientists at NIH are investigating the unique characteristics of lamprey fibrinogen and the cross-linking factors involved in forming the firm clot, in an attempt to understand the mechanisms involved in clot formation and subsequent hydrolysis in fish and humans exposed to traumatic conditions. Several articles that advanced understanding of the specific mechanisms involved were published.

Effects of dietary carbohydrates and minerals on growth of salmonids in cold, mineral-poor water.—One major challenge in rearing salmonids in the northwestern United States is the formulation of diets that not only are reasonably priced but also compensate for the acidic, mineral-poor quality typical of many snow-melt waters. A second is that of facilitating growth at suboptimal temperatures. In addressing these challenges, biologists of the Western Fish Nutrition Laboratory have evaluated the role of carbohydrates as inexpensive, easily assimilable energy sources and have increased the amounts and kinds of dietary minerals to ease the fish's osmoregulatory burden in poorly mineralized water.

A total of 55 dietary formulations were tested on coho and chinook salmon and rainbow and steelhead trout. In these diets carbohydrates, alone and in combination, made up 28% of the dry weight; protein content was 36%, 50%, or 60%; and the mineral portion ranged from 4 to 13%. Seven significant results of this study follow: (1) The polyhedral alcohol glycerol appears to be a good energy source in a starter diet for rainbow trout reared at 10° C. Maltose, sucrose, and glycerol may improve feed

conversion in a coho salmon starter diet at 10° C. (2) At low rearing temperatures (5-6° C), fructose enhanced early growth in rainbow trout; glycerol may serve a similar function in coho salmon. (3) At 10° C steelhead trout responded as well to inclusion of 28% dextrin in the diet as to the inclusion of a mixture of 8% dextrin, 14% glucose, and 6% glycerol. (4) Doubling the usual content of salts in the standard H440 control test diet and supplementing this with a mixture of calcium salts (5.5% dry weight) significantly bettered the feed conversion rate of steelhead trout reared at 10° C. (5) Feed conversion rate of chinook salmon reared at 10° C improved when they were fed mineral-supplemented modifications of the H440 control test diet. (6) In a comparison of three production diets—the Oregon Moist Pellet salmon diet and the Spearfish Diet Center formulations SD-5 and SD-6—feed conversion rates for fall chinook salmon reared at 10° C were 1.11 for the Oregon diet, 2.30 for SD-5, and 1.36 for SD-6. The conversion rate for fish on the H440 standard test diet was 1.24. (7) Incorporation of the minerals selenium, fluorine, molybdenum, and chromium in trace amounts (0.02%) in the diet depressed growth of coho salmon to only 31% of that of fish fed the H440 control diet. When incorporated at 0.04% of the diet, feed conversion was seriously affected (10.26 vs. 0.79 for the H440 diet); and at 0.08%, large-scale mortalities occurred within 6 weeks after the start of feeding.

The "standard line" Fish Genetics Laboratory strain of rainbow trout did not fare well in diet tests. Perhaps a strain adapted to hard water is adversely affected by acidic, poorly mineralized water.

Inhibition of growth of steelheads fed diets containing short-chain fatty acids.—The 4-, 6-, and 8-carbon fatty acids and their triglycerides inhibited and sometimes halted the growth of steelhead trout. Materials compared with cod liver oil as dietary fats were the 4-, 6-, 8-, and 10-carbon fatty acids and their triglycerides; coconut oil; triolein; corn oil; and linseed oil. The fatty acids were fed at 5% of the diet, in addition to 4% linseed oil, in a complete test diet. Each diet was fed to both underyearling and yearling steelheads for 10 months. At the conclusion of the experiment, steelheads fed the 4- and 6-carbon fatty acids or their triglycerides were only about 12% the size of those fed intermediate- or long-chain fats. An examination of the effect of the types of diet on peristalsis gave no positive explanation for the mechanism of action of these fatty acids. The inhibition may be a major factor in toxicity of rancid feeds which contain some of the same short-chain fatty acids.

Detrimental effect of high fat content in a low protein diet for coho salmon.—Coho salmon were fed a synthetic diet of 4% marine oil and up to 18% coconut oil, with less than 35% protein, showed growth inhibition if fed more than 4% dietary fat. At higher protein levels, maximum growth was attained by fish fed less than 10% dietary fat. It was not determined whether the type of fat, in addition to the amount, affected growth, nor whether the essential fatty acid requirement was affected by the protein content of the diet. Measurement of the individual fatty acids in the heart and liver gave no evidence of an essential fatty acid deficiency. These results indicate that a high fat level must be avoided in certain fish feeds.

MIGRATORY BIRDS

Migratory Bird and Habitat Research Laboratory

Field tests comparing lead and steel shot for hunting waterfowl.—Lead shotgun pellets are known to be toxic when ingested by waterfowl. As a substitute for lead shot in waterfowl hunting, steel shot was evaluated in a cooperative Federal-State research program during the 1973-74 and 1974-75 hunting seasons at 13 locations in 11 States. Hunts in which lead was used were matched as nearly as possible with hunts in which steel was used. Hunters using lead shot downed 902 ducks with 3,762 shots for a rate of 240 ducks downed per 1,000 shots fired. They failed to retrieve 150 of the 902 ducks for a loss rate of 16.6%. Hunters using steel shot downed 946 ducks with 4,105 shots for a rate of 230 ducks downed per 1,000 shots fired. They failed to retrieve 179 of the 946 ducks for a loss rate of 18.9%. Hunters using lead downed 194

geese with 1,626 shots for a rate of 119 geese downed per 1,000 shots fired. They failed to retrieve 36 of the 194 geese for a loss rate of 18.6%. Hunters using steel downed 215 geese with 1,688 shots for a rate of 127 geese downed per 1,000 shots fired. They failed to retrieve 36 of the 215 geese for a loss rate of 16.7%. None of these differences between the use of lead and steel shot for hunting waterfowl was statistically significant.

Mallard population ecology.—A series of reports on mallard populations has been in preparation for several years. In 1975, the work neared completion with the preparation of reports on mallard harvest and survival. Prior to 1960, when mallard hunting regulations were less restrictive, about 43% of the ducks shot by U.S. hunters were mallards. Since that time mallards have made up about 33% of the duck harvest.

Adults of both sexes survived at a significantly higher



The perfect ending of a duck hunt in the Central Flyway—two male mallards and two lesser scaup. Analysis of data for reports on mallard population dynamics is aimed at more effective conservation, use, and regulation of the mallard resource. (Photo by J. T. Lokemoen)

rate, statistically, than young, and adult males had a higher survival rate than adult females. Averaged over geographic areas and years for approximately the last 2 decades, the annual survival rate of adult males and females is estimated to have been 62% and 54%, respectively. Comparable figures for young were 48% for males and 46% for females. Proportionally more males than females were taken by hunters and more young than adults. Sport hunting removed a very substantial fraction of the population in some years. No trends in survival were found for the years that banding records were analyzed.

Population fluctuations were probably more closely associated with annual changes in recruitment than with annual changes in survival rates. The mean life spans of adults and young were approximately 1.8 and 1.2 years, respectively. The average prehunting season sex ratio of

adults is estimated to have been 1.2-1.3 males per female. Hunting can affect the survival rate of the population in two ways: (1) hunting represents an additive form of mortality, and (2) hunting mortality, below some threshold level, is compensated by decreases in other forms of mortality. Results support the hypothesis that hunting mortality, when properly controlled, has been, for the most part, offset by decreased natural mortality, at least to some threshold level. Unfortunately, it may be easy for harvest rates to exceed this threshold level on a local basis, for example, on breeding grounds or areas where birds may be particularly vulnerable.

Special canvasback studies.—Canvasback studies in the Chesapeake Bay emphasized feeding ecology during the reporting period. The findings indicated that the Balthic clam (*Macoma balthica*) was the primary food of canvasbacks in the Bay during 1975. This soft-shelled



Organisms in the bottom of a body of water provide food for waterfowl. The organisms are sampled with this device, called a Petersen grab. (Photo by M. C. Perry)

clam, usually less than 1 inch long, occurs commonly in the Bay where salinity is approximately one-half sea strength. Aquatic vegetation, the traditional food of canvasbacks in the Bay, has declined in recent years because of increased turbidity and other environmental changes. The canvasback adapted to the decrease in plant food by feeding on clams.

A sample of 501 canvasbacks were trapped and fluoroscoped to determine the occurrence of shotgun pellets lodged in their flesh. The measurement, which serves as an indicator of hunting pressure, revealed a significant difference in the incidence of shot between adults and immatures. Thirty percent of the adults as opposed to 13% of the immatures were carrying shot. This is expected because adults have been exposed to more hunting seasons than immatures.

Techniques for appraising snow goose productivity.—In recent years, the estimated population of the greater snow goose has increased dramatically. Much of the increase was detected from photographs taken by the Quebec Wildlife Service on the St. Lawrence staging area. Counts made from those photographs indicate that the population is nearly twice as large as previously estimated. Also, wintering flocks have shifted from coastal marshes to agricultural fields for feeding.

In addition to population estimates, accurate and timely estimates of annual productivity are needed. Nesting success is influenced mostly by the timing of the spring melt of ice and snow in the Arctic. Remote sensing imagery from satellites can predict years of total reproductive failure due to delayed spring break-up. However, the technique cannot predict magnitude of production in other

years. Onsite or aerial inspections of molting flocks in late July can provide a good estimate of productivity. Low-level photography can help quantify the estimates. However, all colonies must be examined by the use of chartered aircraft, which is extremely expensive and subject to vagaries of Arctic weather. The next opportunity for estimating production (with high-level photography) is in October, when most of the population is concentrated on the St. Lawrence River. The photographs must be taken at peak population because there is some differential migration. After the geese arrive on the wintering grounds in November, counting family groups becomes the most practical technique for estimating production. Its advantages are low cost and the opportunity for collecting supplementary data on family size and structure. A shortcoming is that family group data are obtained too late to affect regulations in Canada or the United States.

Both satellite photographs and onsite inspection in mid-June 1974 at Bylot Island, the main nesting area of the greater snow goose, indicated little or no reproduction



Greater snow geese on their wintering grounds. Fish and Wildlife Service biologists are studying methods of estimating populations and productivity of this species. (Photo by L. C. Goldman)

because of a late thaw. A subsequent banding drive on Somerset Island and aerial examination of other molting flocks led to an estimate of not more than 1% immatures in the fall flight. This low ratio was confirmed by field appraisals on the wintering grounds. Group counts of 6,148 geese wintering in New Jersey gave an estimate of 1.5% immatures; sub-sample counts of 37 families averaged 2.2 young per family. Another sample of 2,130 geese wintering in North Carolina contained 3.6% immatures. Overall recruitment, based on population strata, was 2% immatures.

Appraising annual productivity of Atlantic brant.—The brant population wintering along the Atlantic Coast plunged to a low level in the early 1930's. The decline was generally attributed to a fungus-like disease that devastated eel grass, a major food. The brant population increased slowly during the 1930's and 1940's, and Atlantic brant became comparatively plentiful in the 1950's and 1960's, despite liberal hunting seasons. Arctic nesting conditions were unfavorable in 1971 and few young were produced. An exceptionally large kill by hunters reduced the population to 73,300 by January 1972. A complete reproductive failure that summer further lowered the population to 40,700 by January 1973 despite a closed hunting season. Fortunately, nesting conditions were excellent in 1973 and nearly 60% of the fall population consisted of immatures.

Prior to 1970, age ratios in the fall population were based on a sample of hunter-killed birds. Such samples are biased by a higher kill rate of immatures. Since 1970, age ratios have been obtained directly from the population by examining flocks through a spotting scope. For several years thereafter, all brant within observational range were identified as adult or immature, but no effort was made to stratify flocks by size or location or to identify family groups. In 1973 and 1974 techniques were developed to provide a better sample of age ratios and to obtain supplementary data on average brood size and percentage of productive adults.

Field appraisals in November 1974 showed that 12.1% of 3,653 brant in New Jersey and on Long Island, N.Y., were immatures. A sample of 105 families averaged 2.58 young per family and about 26% of adult pairs produced young. The productivity of brant wintering on Long Island was slightly higher than that of brant wintering in New Jersey.

Family groups indicate productivity of sandhill cranes.—Field age determinations of 9,147 sandhill cranes, compiled in October along the Texas-New Mexico border, revealed an overall age ratio of 0.108 juvenile per adult. A detailed examination of small groups showed that 222 families averaged 1.16 young per family; 16.2%

of families contained 2 young. Earlier publications reported that families with two young were rare.

Primary feather molt in mourning doves.—Recapture records on 1,630 immature mourning doves banded in North and South Carolina were used to determine the time at which primary feathers are molted. The molt began at 38 days of age and ended in 131 days with the loss of the 10th primary. The time of molt did not vary significantly between sexes or among years. The results of this 7-year study are in agreement with earlier research in Indiana and indicate that this technique is a reliable means of determining the time at which the doves hatch.

Unretrieved loss of mourning doves in South Carolina.—Unretrieved loss accounts for the portion of the population that dies as a result of hunting but is not retrieved by the hunter. It is important in understanding the effects of hunting on mourning dove populations. This loss of mourning doves was examined in South Carolina as part of the research underway at the Carolina Sandhills Dove Field Station.

One hundred and twenty-six hunters were observed for 392.8 hunting hours by observers posing as hunters in 1973-74. The unretrieved loss was estimated at between 23.2 and 29.0% of the total kills. The low estimate included only fallen doves that were not retrieved; the high estimate included birds that continued to fly but were obviously hit. The true unretrieved loss lies between these two estimates. Although retriever dogs increased the efficiency of hunters, only 4% or 667 hunters encountered during the study used retrievers.

Comprehensive study of mourning dove breeding biology.—Preliminary findings from a study in South Carolina are providing new and useful information on the calling behavior, movements, and habitat preferences of male mourning doves. The research is being conducted to evaluate reliability of the dove call-count survey and to identify preferred habitats. Activities of the birds are being monitored by means of radio transmitters attached to their backs. The home ranges of six mated males averaged 3.2 square miles but the average was only 1.4 square miles for three unmated males. During the first 3 hours after sunrise, mated males frequently moved several miles from their roost to feed in open fields and rest in trees. During this period they ranged as far as 2 miles from their nests. Late in the morning they returned to their nests, exchanged places with their mates, and incubated through most of the day. Preliminary findings from this study have confirmed earlier work establishing that unmated males called more frequently than mated males and, thus, were more likely to be recorded during the call-count survey. However, the current study suggests that mated males call much less frequently than suggested



A group of sandhill cranes. The number of juvenile birds in family groups can provide information on recruitment to the sandhill population.

(Photo by L. C. Goldman)

by other investigations and that they range much farther from the nest.

Research on migratory shore and upland game birds.—The Migratory Bird and Habitat Research Laboratory currently administers special funds to State conservation agencies and universities for research on migratory shore and upland game birds. This program was initiated in 1968 to obtain information needed for more effective management of these birds. During fiscal year 1974-75, 39 studies funded by the Accelerated Research Program were underway in 30 States. Species studied included band-tailed pigeons, clapper rails, mourning doves, coots, common snipe, woodcock, and sandhill cranes. Types of research varied. One study focused on developing techniques for estimating unretrieved loss associated with mourning dove hunting; another study dealt with the breeding-ground origin of wintering populations of clapper rails along the Gulf Coast of Alabama. In addition, personnel of the International Association of Game, Fish and Conservation Commissioners, in cooperation with biologists of the U. S. Fish and Wildlife Service, have undertaken the major task of assembling in-

formation on migratory shore and upland game birds. The book to be published will include descriptions of current distribution, population status, management requirements, and research needs. It will add greatly to our present knowledge and provide guidance for improved management of shore and upland migratory birds.

Breeding-bird Survey reveals population trends of migratory birds.—With 9 consecutive years of coverage in the eastern region, 8 in the central region, and 7 in the western region, the Breeding-bird Survey can detect long-term trends in bird populations along roadsides throughout most of the United States and southern Canada. The number of comparable routes covered in both 1973 and 1974 reached a new high of 1,541. The most striking changes have been increases in the cattle egret (average increase of 12% per year for 1966-74) and the house finch (22% per year) in the eastern region, the starling in the western region (16% per year for 1968-74), and a decrease in the black tern in the eastern and central regions (15% per year). The yellow-shafted flicker and red-headed woodpecker have declined slowly and steadily at an average rate of 3% per year in the East.



The mourning dove is an important migratory game bird in many States.

Hunting regulations are based on a coo-count survey which gives an index to changes in numbers from year to year. (Photo by J. Thompson)

Five consecutive days of cold, rainy weather in northern New England resulted in a massive kill of scarlet tanagers in Maine and New Hampshire on 25-26 May 1974. Later in the year, the Breeding-bird Survey showed declines from the previous year of 30% in New Hampshire and 50% in Maine. Other species apparently suffered from the same rainy spell in parts or all of northern New England and the Maritime Provinces; the survey recorded decreases of 25-30% for tree, bank, barn, and cliff swallows and black-and-white, Nashville, parula, magnolia, and chestnut-sided warblers.

Data bank of breeding bird censuses.—A computerized bibliography of breeding bird censuses by habitat has been compiled during the past 2 years. This now contains bird population data from more than 1,600 published studies conducted from 1919 through 1970. For each census plot the computer record contains a habitat code, 3 dominant plant species, latitude, longitude, elevation, the population and density of each of the 12 commonest bird species, and the total population. Because data can be retrieved by any combination of the above categories, the file will have many uses.

A comparison of the species diversity indices by major habitats, based on a sample of 185 different census plots, shows that the highest average species diversity (2.58) was in deciduous woodland, followed by mixed deciduous-coniferous (2.55), coniferous (2.46), mixed fields and woods (2.38), brushland (2.27), suburban (2.11), marsh (2.00), grassland (1.66), and desert (1.13).

As an example of the effects of management practices on bird populations, a comparison made between a grazed sugar maple woodland and an adjacent smaller plot protected from grazing for 10 years indicated nearly 3.0 times as many bird species and 4.5 times as many birds per 100 acres in the protected plot. Construction of an interstate highway initially reduced the bird population in an adjacent upland oak forest to about 40% of the previous average; 3-5 years later the breeding density had recovered to only 55% of the original population density and to 84% of the original number of breeding species. Documentation of the permanent loss of characteristic breeding species when woodlots are divided by highways or isolated from adjacent similar habitat by changes in land use is an especially valuable contribution of these censuses.

National Fish and Wildlife Laboratory

Investigation of terns.—Breeding colonies of terns on



Coots are among the migratory shore and upland game species that are being studied by the accelerated Research Program in cooperation with State conservation agencies and universities. (Photo by C. J. Henry)



Sanderlings probing for invertebrates at low tide. Competition among species of shorebirds is reduced by selective use of microhabitats and by temporal patterns of foraging in relation to tidal rhythms. (Photo by L. C. Goldman)

the barrier islands of Virginia and Maryland were examined in 1974 and populations were estimated. Approximately 2,000 young royal terns (essentially all that were fledged) and samples of the young of associated species were banded. An additional 1,100 young royal terns were banded in North Carolina. Among 242 captures of adult royal terns by nightlighting, 22 (9%) had been banded previously. Breeding range extensions were discovered for the Caspian and Sandwich Terns. Computerized band recovery data, provided by the Bird Banding Office for royal terns, are being analyzed. A report of the locations, species composition, and numerical size of the colonies was prepared and distributed within the Fish and Wildlife Service and to interested conservation societies in the region.

Shorebird behavior.—Three weeks of intensive field work in August at Brigantine National Wildlife Refuge, N. J., provided data on feeding behavior, microhabitat utilization, and tidal response patterns of migrating shorebirds. Collaborating in the study were J. Burger, D. J. Chase, and D.C. Hahn of Rutgers University. Each species studied showed a distinct temporal pattern of using exposed mudflats in relation to tidal rhythms. Competition was further reduced by selective use of different recognizable microhabitats by different species on the

mudflat. Aggressive behavior was common in shoreline feeding situations but was largely intraspecific, even in dense mixed-species aggregations. Feeding rates vary between species and within species in different habitats. In some cases changes in feeding method by the shorebirds can be predicted when one method reaches a certain level of inefficiency.

Avian adaptations to grasslands.—A survey of shortgrass prairie areas on the Pawnee National Grassland indicates that McCown's longspur is an ideal subject for studying avian adaptations to that habitat. A study site was marked off in squares and the population density and territory sizes of the species were measured repeatedly throughout the season. Territorial behavior, use of space, growth rates of young, and other aspects of breeding biology were studied. Preliminary results show that territory size and site location varied little for individual birds during the breeding season. Nests were positioned immediately northeast of small forbs to afford protection from the hot afternoon sun. Both parents remained with the young after they were fledged, but the male stayed with them longer, allowing the female to renest as soon as possible. During dry periods cattle tanks were used for drinking, suggesting that these artificial sources of water may have increased reproductive potential in dry years.

Data from an intensive vegetation analysis are being evaluated to determine if breeding success correlates with certain vegetative characteristics of the bird territories.

Northern Prairie Wildlife Research Center

Nesting ecology of the ferruginous hawk.—Results of intensive spring surveys revealed that ferruginous hawk densities were one pair per 7 square miles—the highest density recorded within its breeding range. Density of total raptors was one pair per 4 square miles, lower than that reported for most other areas. The low population of total raptors was probably caused by a lack of habitat diversity and the dominance of the ferruginous hawk. The study area contained no steep ravines or cliffs, and woodlands cover only 0.3% of the land surface. The ferruginous hawk is adapted to nesting in this open prairie environment and utilizes the ground, haystacks, and trees for nest sites. Other buteos and great horned owls nested only in trees.

Ferruginous hawks arrived on the area in March or early April. Nest building began soon after arrival and egg laying was completed in mid-April. Most clutches hatched by late May and some young were making short flights by late June. Nest success averaged 59% and 1.8 young were fledged per pair. Tree nests were generally more successful than ground nests, mainly because ground nests were destroyed by red foxes and other predators.

Nutritional requirements of breeding waterfowl.—A 7-year investigation of factors influencing the selection of foods by four species of ducks (the pintail, blue-winged teal, shoveler, and gadwall) during the breeding season in the glaciated prairie region of south-central North Dakota

showed that the diet of laying hens was dominated by invertebrates. The proportion of animal foods in the diet increased at the onset of the nesting season. The plant and animal communities that were utilized by the breeding ducks fluctuated drastically in response to the adjustment of the prairie aquatic ecosystems to seasonal, annual, and long-term changes in evaporation-precipitation ratios. A controlled study undertaken on experimental ponds suggests that egg production can be influenced by this wetland quality.

As a part of this total effort, one recently completed study demonstrated the nutritional significance of invertebrate foods in the diet of prairie nesting pintails. Animal foods selected by pintails during the nesting season are rich sources of both protein and calcium. Conversely, the plant foods tested were low in protein, particularly in the essential amino acids, lysine and methionine. Plant foods did not contain adequate calcium for egg production. Aquatic invertebrates and earthworms were found to be important food items of laying pintails. Initiation of pintail nesting and availability of both aquatic invertebrates and earthworms are often associated with wet periods in the early spring. Egg formation may be triggered by the availability of this rich source of food during that period.

Predators affecting waterfowl production.—Studies on predator-prey relationships in prairie ecosystems have been conducted for several years. The work on the red fox, now nearing completion, required investigations as diverse as death feigning by ducks to avoid fox predation and development of techniques to census red foxes. To more fully understand the impact of red fox predation on waterfowl, the ecology of both the predator and the prey had to be studied. The data indicate that this species is having a considerable impact on mallard production in North Dakota and probably in other parts of the prairie pothole region as well. Historical evidence shows that red fox populations are larger now than before settlement when both the wolf and coyote acted as population checks on the red fox. The red fox is an efficient predator of nesting dabbling ducks, and nesting hens are much more vulnerable to fox predation than drakes. This research has provided evidence that the red fox plays a significant role in the disparate sex ratio of the North Dakota mallard population.

Application of remote sensing to ecological research in the prairie regions.—Information on numbers, distribution, and quality of wetlands in the glaciated prairie region are important indices for predicting waterfowl production. Data collected from satellites have a potential for complementing and enhancing current survey programs. A study conducted in cooperation with the National Aeronautics and Space Administration and the Environmental Research Institute of Michigan has indicated that



Fully fledged young ferruginous hawks near their nest. This species is decreasing in numbers because of the encroachment of croplands on its natural grassland habitat. (Photo by R. E. Steward)



Fox rearing den with 8- to 10-week-old pup and typical food remains including wings of several ducks. The red fox is an efficient predator of nesting dabbling ducks. (Photo by A. B. Sargeant)

data acquired from the first Earth Resources Technology Satellite (ERTS-1) can be of value if converted by computer-aided reduction techniques. Several methods for processing ERTS-1 data were developed. Earlier single-waveband recognition techniques consistently detected ponds having a minimum size of 4 acres. More advanced multispectral techniques tested in this study reduced the minimum discernible water feature by a factor of 3 and improved the size and shape definition of the larger ponds and lakes. These improved techniques will allow for detection of smaller ponds which are very important in waterfowl habitat. In future operational systems, the most accurate and economically feasible methods for monitoring open surface water will likely involve techniques developed or tested in this study.

Time budget of breeding gadwalls.—Time budget studies of breeding gadwalls were conducted to determine how activities such as feeding, nesting, locomotion, preening, bathing, threat, chases, and alert behavior relate to the reproductive strategy of pairs. The time budgets calculated for pairs of gadwalls, were based on 71.2 hours of observation. Feeding occupied the greatest proportion of the time for female gadwalls during the spring arrival, prenesting, and laying phases of the breeding season. Feeding rates for prenesting and laying females were significantly greater than for their mates regardless of the time of day. Paired males spent a maximum amount of time chasing other pairs during the prenesting phase. Feeding rates did not change significantly for males or females during the day in the prenesting or laying phase.

Gadwall drakes apparently use more energy chasing other pairs than in chasing unmated drakes. Mated drakes help to assure the reproductive output of the pair by maintaining an exclusive feeding area for the female before and during the time of egg formation.

Patuxent Wildlife Research Center

Roads and wildlife populations.—The Federal Highway Administration recently contracted with the U. S. Fish and Wildlife Service to conduct a 5-year study of wildlife habitat and populations associated with various types of roads. This study will result in an extensive volume of data on birds, mammals, reptiles, and amphibians collected at various distances from both major highways and lightly traveled roads. It will provide a basis for understanding the relationships that exist between roads, habitat, and wildlife. The work will be done in four important parts of the United States: the Southern Piedmont, from Virginia south to Alabama; the Tillplain area, from western Ohio through Iowa; the Humid Pacific Coastal Region, west of the Cascade Mountains in California, Oregon, and Washington; and an area in the Southwest. The initial phase of this study leading to recommendations for a standardized data collection program is now in progress.

Effects of building design and quality on urban bird species.—Research on effects of building design and quality on breeding populations of nuisance birds in urban situations was continued during the summer of 1975. Subtle differences in building design were found to have a striking effect on breeding populations. For example, in the new city of Columbia, Md., one type of vent was consistently used as nest sites by house sparrows (1.2 nests per vent) while the other type was not. This difference was due solely to the design of the vent. Those used frequently by house sparrows for both nesting and roosting were square with a round facade on the outside providing protected crannies in the corners of the vent.

Land use planning concepts investigated.—A pilot study was carried out in Fairfax County, Va., to better understand the wildlife implications of the county's land use planning proposals. Bird counts were made systematically in flood plains, adjacent uplands, and areas tentatively restricted from development because of their wildlife value. These data will not only yield information on the differences in bird populations associated with various areas, but more importantly they will provide a basis for planning more detailed studies to understand the potential effects on wildlife of present land-use planning concepts.

Bird survey and management in urban areas.—Data were collected in Columbia, Md., Baltimore, Md., Chicago, Ill., and near Philadelphia, Pa., on factors af-



Gadwall duck and nest with newly hatched ducklings. The breeding behavior of this species is under investigation in North Dakota.
(Photo by C. J. Henry)

fecting the accuracy of urban bird surveys. Factors such as time of day and wind velocity were found to have less effect on urban bird counts than on counts in "natural" areas. In the Philadelphia study, counts made in the evening were highly correlated with those made in the morning, suggesting that, where human disturbance is not high, counts can be made in the evening as well as in the usual morning period.

Research on the relative attractiveness of various plant materials such as millets and sorghums in urban bird food plots continued. Also tests were begun on eight varieties of crab apples, identified by the New York Department of Environmental Conservation as being highly attractive for wildlife. Scion wood provided by New York was successfully grafted into wild apple trees growing in old field areas in Columbia, Md. These will provide a basis for comparing the varieties superior for wildlife with those commonly used for ornamental purposes.

Washington, D.C., Office

Human related bird mortality.—Estimates of annual avian mortality resulting from various human activities total nearly 195 million birds. Hunting, for which data are most accurate, is the primary activity and accounts for 120 million birds or about 62% of the deaths caused directly or indirectly by humans. Four species of birds—mourning dove, bobwhite quail, ring-necked pheasant, and mallard—make up about 75% of the hunting mortality and 40% of all human-caused bird deaths. Collision with man-made objects results in the deaths of an estimated 62 million birds (highway mortality alone accounts for 57 million) or 31% of the birds that die directly or indirectly because of man. The least important of the human-related mortality factors are activities by holders of scientific collecting and other special purpose permits and oil spills. All of the human-related bird mortality, however, amounts to about 2% of the approximately 10 billion birds

that must succumb annually to mortality of one kind or another in order to offset reproduction and maintain stable populations. Other activities of man, such as habitat alter-

ation and environmental contamination, may have long-term effects on bird populations by reducing reproductive potential rather than causing mortality.

MAMMALS AND NONMIGRATORY BIRDS

Denver Wildlife Research Center

Deer mice eat arthropods.—Stomach samples collected from deer mice on eight experimental watersheds in the salt-desert shrub vegetative type (of the Badger Wash Experimental Area, western Colorado at 5,000 feet altitude) were separated by months (May, August, and October), composited by watershed, and examined for food content by microscopic methods. Four of the watersheds were grazed in winter by sheep and four were ungrazed.

There was little difference between paired watersheds or among collection periods in the kinds of food found in the stomach samples. The samples did show, however, that deer mice on Badger Wash ate arthropods. This may have provided some benefit to range plants by lessening the number of insects that fed on plant parts and seeds. Discernible arthropod fragments made up 55-96% of the contents of the eight composited stomach samples in May, 22-81% in August, and 86-100% in October. The most common insects eaten were larvae of butterflies and moths and adults of the grasshopper, wasp and bee, and beetle groups. The deer mice also ate some seeds and plant parts, but probably not enough to adversely influence the vegetation on either the grazed or ungrazed range.

This investigation was part of a cooperative study with U.S. Geological Survey, Bureau of Land Management, and Bureau of Reclamation to learn what influence the exclusion of livestock would have on runoff, sediment yields, vegetation, and animal populations on salt-desert range.

Winter foods of northern pocket gophers on high-altitude rangeland.—The herbivorous northern pocket gopher is an inhabitant of the high-altitude summer range used by cattle and sheep in the Rocky Mountains. Pocket gophers have long been considered competitors with livestock for forage and contributors to poor range conditions.

The winter feeding habits of northern pocket gophers on Black Mesa Experimental Forest and Range, Gunnison National Forest, in west-central Colorado, were investigated by collecting animals six times during November through May. Stomach samples taken from the animals were composited by month and food items were determined by microscopic methods. Because the experimen-



Northern pocket gophers feed actively during the winter by tunneling under the snowpack. As the snow recedes in the spring, food caches of common dandelion roots (top) and clipped stems of rabbitbrush (bottom) become revealed. (Photo by V. H. Reid)



Measuring annual production and utilization of paper birch is part of a research project on moose at the Kenai National Moose Range in Alaska.
The photo shows a regrowth of spruce and birch. (Photo by J. L. Oldemeyer)

tal area is usually covered with snow from late October through late May, the stomach samples represent the animals' diet beneath the snowpack. The peak snowpack, which usually occurs in April, averages 55 inches deep.

Grasses and forbs were the most common winter foods. Other studies have shown that forbs are also important foods in summer and fall, but the species composition was different. For example, leaves and stems of aspen fleabane, agoseris, common dandelion, hairy goldaster, and yarrow were major food items in summer. In winter and early spring, about 80% of the identifiable plant fragments were roots of common dandelion and stems of rabbitbrush.

The investigation suggests no serious conflict between winter feeding by pocket gophers and summer grazing by cattle on Black Mesa. The cattle do graze dandelion when they first arrive in summer but eat very little as summer advances; they eat very little rabbitbrush.

Lack of variety in winter browse for Kenai moose.—Moose populations on the Denali National Moose Range have been declining over the past several years. Part of the reason appears to be the lack of species diversity among the browse plants available in the 1947 burn on the north-

ern lowlands of the Range. To determine if there are important nutritional differences among browse species, the quality of moose browse was evaluated by determining in vitro drymatter digestibility, fiber, protein, and mineral levels. Concentrations of these nutrients and minerals changed significantly between summer and winter in the five major browse species—paper birch, aspen, willow, alder, and lowbush cranberry. Minerals also differed greatly between the two summers sampled, the plant parts, and the sampling periods in a summer.

These significant differences among browse species demonstrated the importance of variety in the diet of moose and other browsing animals. For example, alder and birch supply higher levels of protein in winter, whereas willow and lowbush cranberry are better digested and contain higher levels of calcium. All five winter browse species in sufficient quantities can better meet the nutritional needs of moose than one species.

Effects of logging and burning on small-mammal populations.—The forest mosaic of the northern Rocky Mountains is undergoing rapid change as old-growth forests are cut and young, even-aged stands succeed them. The cutting, followed by controlled burning to remove

unused logging slash and create bare-soil seed beds, has important effects on small mammals and other wildlife. A continuing study is being conducted in cooperation with the U. S. Forest Service to determine the effects on small mammals of cutting and controlled burning in 200-year-old stands of larch, spruce, and Douglas-fir.

Initial observations after 5 years of small mammal trapping indicate that red-backed voles predominated in the uncut forest. However, vole populations fluctuated markedly in both cut and uncut forests. Deer mice were present in uncut forests but increased and became predominant when the herbaceous and succulent plants became abundant after burning. Populations of deer mice showed a gradation between habitat extremes, with the highest populations in dry, open habitat and early successional stages. Chipmunks were eliminated by fire but returned about the 3rd season after a burn and increased thereafter.

Eleven small mammal species, three big game species, two grouse species, and numerous species of nongame birds were associated with cutovers and the adjacent uncut timber. Of over 1,100 small mammals caught to date, 96% have been deer mice, red-tailed chipmunks, and red-backed and long-tailed voles. Thus, just four species accounted for most of the small mammal biomass. Which of the four predominated was related to local habitat conditions such as moisture and aspect.

These initial findings should help forest management planning. Although some species recovered very slowly after cutting and broadcast burning, deer mice increased quickly and chipmunks recovered within 2-3 years. These species must therefore be considered in natural or artificial seeding programs.

Wild turkey populations decline in pinyon-juniper control areas.—Approximately 1.7 million ha of pinyon-juniper woodland in Arizona is inhabited by the Merriam's turkey. This range generally parallels the ponderosa pine belt of Arizona where small stands of the pine are found in valleys and on north-facing slopes. Small groups of the pines provide roosting sites for the turkeys and probably are necessary for them to survive in the pinyon-juniper habitat.

Evidence accumulated during a 9-year study on a portion of the Fort Apache Indian Reservation indicated that pinyon-juniper eradication programs, usually intended to increase forage production or water yields, can have detrimental effects on turkey populations if not properly designed. Following removal of approximately 800 ha of pinyon-juniper in a single block, turkey populations declined significantly ($P<0.05$) in spring, summer, and fall. (Winter populations were not studied because of access problems.) The most significant seasonal change occurred in summer, when the observed number of tur-



Logging, followed by burning to remove the slash, changes the wildlife environment dramatically, as in this western Montana experimental area. Changes in small mammal populations are being studied as a new plant community develops to replace the forest (background) that was removed. (Photo by C. H. Halvorson)

keys dropped from 0.48/km before treatment to 0.08/km after treatment. A number of roost sites (groups of ponderosa pine trees left standing in the treated area) that turkeys used consistently before treatment were completely abandoned after treatment. Turkeys were seldom observed more than 45 m from cover during the study, and elimination of adequate cover and travel lanes to the roost sites probably accounted for much of the population decline in the area. Pinyon-juniper eradication programs planned for areas containing turkey populations should be designed to leave cover strips and travel lanes to roost sites if the turkey populations are to be maintained.

Breeding bird populations in central Oregon.—Bird populations were censused by the spot-mapping method in central Oregon from 1971 to 1973 to provide reference data for relatively undisturbed sagebrush, juniper, ponderosa pine, and lodgepole pine habitats. Study areas were established to monitor bird populations over long periods of time and for future comparison with similar habitat which has been altered by biological, mechanical, and chemical methods. Average populations of singing males on the four areas for the 3-year period ranged from 91 to 203 per 100 acres. Big sagebrush, with its two-layered plant cover, had the fewest birds, followed in order by lodgepole pine, which is mostly two-layered, and by ponderosa pine and western juniper, which tend to be multi-layered. Plant cover in the arid or semiarid areas of the West lacks the diversity of more humid regions, and this apparently affects the number of bird species frequenting the habitat.



Ponderosa pines isolated by a pinyon-juniper eradication program were abandoned as roost sites by Merriam's turkeys. (Photo by V. E. Scott)

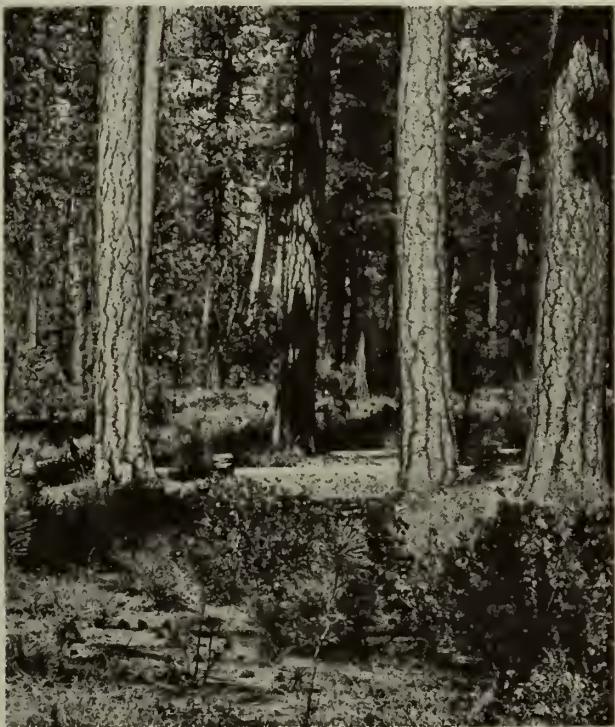
Responses of wildlife to tree and shrub reduction.—A common range management practice on public lands in the West is the reduction of woody vegetation and the establishment of grass-dominated ranges by removing trees and shrubs, seeding, and reducing grazing pressure. Long-term studies were conducted at the Benmore Experimental Range in central Utah to determine the effects of these practices on nongame birds and small mammals in the pinyon-juniper range type.

Trees and shrubs on four areas were removed by dragging a heavy chain between two tractors; then bulldozers pushed the slash into piles or windrows. On one area, part of the slash was burned. Following this treatment, grasses and forbs were seeded, and livestock grazing was deferred for 3 years. In addition, three half-section pastures in an early stage of the grass-sagebrush-juniper succession were burned to study the effects of fire on wildlife. On these areas, 13 species of small mammals were trapped on widely spaced livetraps and 38 species of birds were observed during repeated transect counts, but only two species of mammals and five species of breeding birds

were abundant enough to permit evaluation of treatment effects.

Deer mice, the most commonly caught small mammals, were found in moderate numbers in untreated juniper. They declined slightly the 1st year following mechanical treatment, and then increased to 2 or more times the pretreatment level. Their population continued high for 2-3 years, and then declined to pretreatment levels at 5 years. Pocket mice were severely depleted by the mechanical treatment but gradually increased to pretreatment numbers, or slightly above, by the 2nd or 3rd year. The mechanical treatment eliminated birds that depend on juniper, such as the plain titmouse. Tree and shrub nesters declined or disappeared, and species favoring more open grasslands appeared or increased. Both the number of species and number of birds were reduced the 1st year; they increased to above pretreatment levels the 2nd year, and fell to low levels at 5-6 years.

In the fire-treated areas, each fire had a different intensity and coverage and produced a different response in the resident small mammals and birds. Following a slow,



Big sagebrush (top) and mature ponderosa pine (bottom) are contrasting habitats in the West. Both are important for birds and other wildlife, the first over much of the arid West and the second in the Pacific Northwest. (Photos by J. S. Gashwiler)

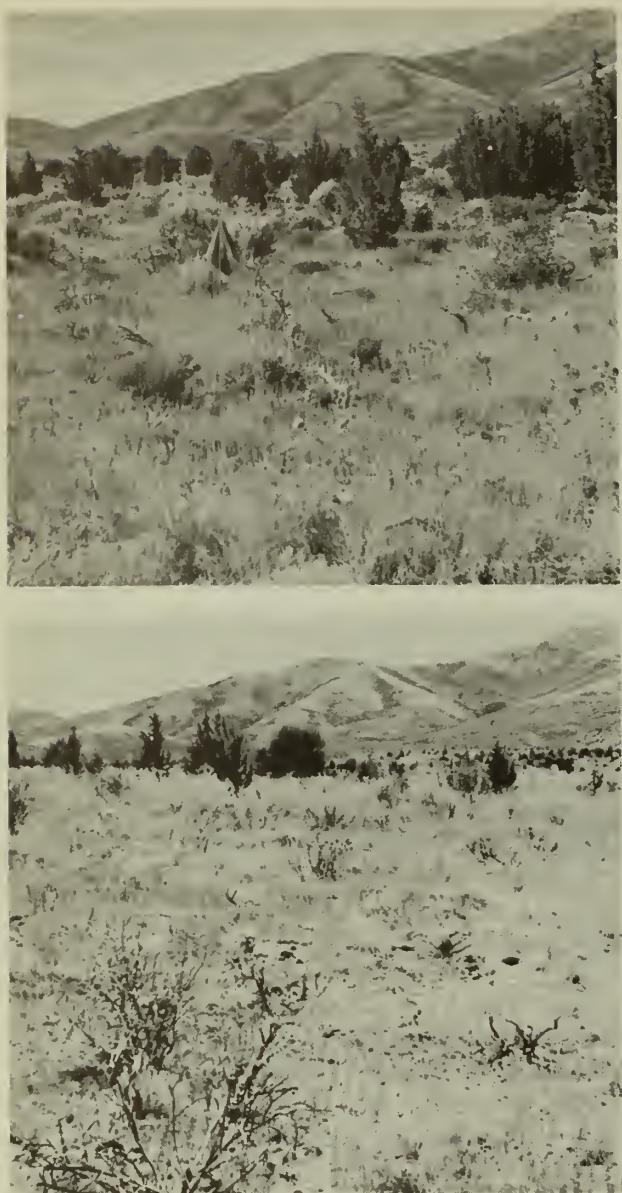
relatively cool fire that burned only the swales, both pocket and deer mice increased dramatically, maintained high levels for 2 years, then dropped to preburn levels. A moderately intense burn resulted in a slight decrease in mammal numbers but no long-term effect. A severe burn reduced pocket mice and eliminated all marked deer mice, but deer mice repopulated the area within 2 weeks and both species had recovered to near pretreatment levels by the 2nd year. No clear-cut changes in bird population density or composition were detected following fire. Shrub nesters, such as Brewer's sparrows, tended to decrease, but the differences were not dramatic, even following the most severe fire.

Either method of woody plant reduction tends to simplify the local habitat and thus reduce the variety and numbers of the fauna. A perfect job of range renovation would leave only a grass-forb habitat and fauna. However, renovations are not complete, and where individual treatments are not too large the fauna may benefit from the diversification of the habitat.

National Fish and Wildlife Laboratory

Pesticide effects on bat populations.—The nursery colony of Brazilian free-tailed bats at Carlsbad Caverns was visited on 27 days from 13 June to 8 September 1974. On these days, infant and adult mortality was monitored by collecting all fallen bats from underneath the roost, and movements and relative numbers of bats in the roost area were noted visually. Also, the composition of the bat population was recorded by periodically sampling the exit flight.

During the extremely dry conditions of early summer, the density of exit flights ranged from very thin to almost nonexistent. Nightly inspection of the roost during this period, however, showed that a much higher number of bats was present than the exit flights indicated. The first rain of the season occurred at 10:00 p.m. on 23 June. Inspection of the roost the following morning revealed no new arrivals, but there was a sudden, dense flight that evening. Although new arrivals were noted on the second morning (25 June) after this rain and again after the second rain of the season, the dense flight on 24 June confirmed the belief that many bats were not feeding before the rains and that the reluctance of the bats to leave the roost was related to the drought conditions, possibly because of low numbers of insects. This year's infant mortality was very high during the drought period (e.g., 2,652 young in first 13 days). This may have resulted from their mothers not feeding every night and thus having low milk supplies or being under stress and abandoning their young. This hypothesis will be tested by comparing the 1973 and 1974 data as to the percentage of fallen young with milk in their stomachs; mammary gland weight, fat



Study area on the Benmore Experimental Range before experimental burning (top) and 1 year after burning (bottom). Tree and shrub cover were greatly reduced, but native grasses survived the fire. Little change in bird and small mammal populations was noted. (Photos by M. F. Baker)

content of mammary gland, and total body fat of lactating females; and chlorinated hydrocarbon residue levels in young. Previous die-offs at Carlsbad Caverns have occurred also during drought years. Explaining this year's infant mortality will contribute to our understanding of past infant die-offs and help in predicting future ones.

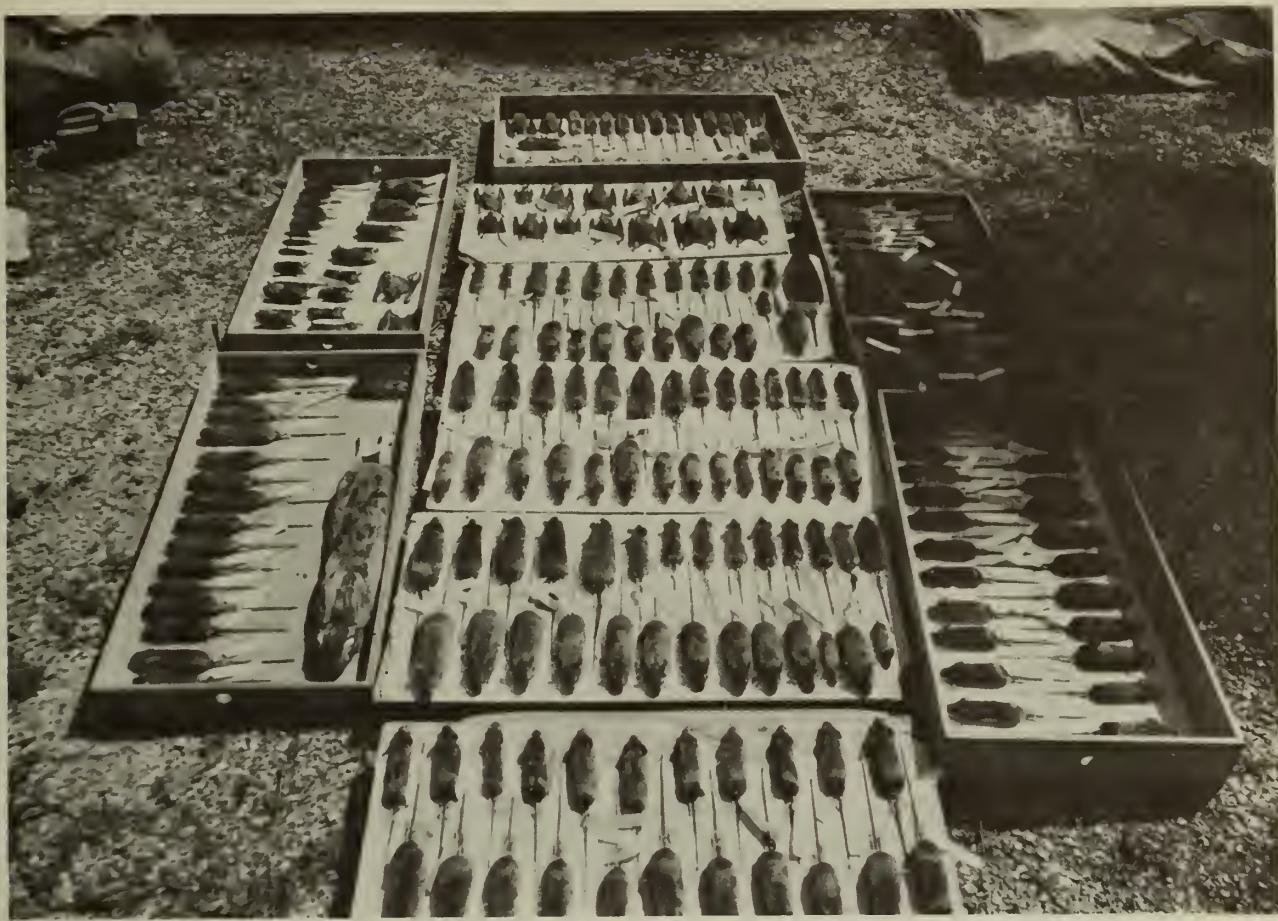
A preliminary study of chlorinated hydrocarbon residues and body fat content in the young bats collected in

1973 suggested that rapid mobilization of body fats during the fall migratory flight may cause high levels of DDE to be liberated into the circulatory system. This has been demonstrated for birds. Because the severity of DDT poisoning is proportional to the amount of DDT in the brain, an increase in pesticide levels in bat brains after migration would be an important step in linking pesticides with bat mortality. To experimentally test this hypothesis, flying young of the year were transported to laboratories at the University of New Mexico before the 1974 fall migratory flight. Bats were then divided into 3 groups: group 1 was immediately killed and frozen, group 2 was kept cold and undisturbed in an environmental chamber, and group 3, the experimental group, was not fed; the bats in the group were kept warm and flown each day in a flight chamber to cause rapid mobilization of their body fat. Chlorinated hydrocarbon levels of both brains and carcasses will be compared between these groups.

Mammals of New Mexico.—The State boundaries of New Mexico, surrounding an area of 121,666 square miles, enclose one of the richest, most diversified mammalian faunas in the world. Presently 139 native species are known to occur in the State, a number exceeded only by California (163) and Texas (156). In the New World, only the highlands of northern Central America have a greater diversity of species. This wealth of kinds is explained by the fact that New Mexico shares the distinctive mammals of several different faunal areas, namely the Rocky Mountains, the Great Plains, the Chihuahuan Desert, the Mexican Plateau, the Sonoran Desert, and the Great Basin. The effect of this mingling is most marked in an area about 400 miles in diameter, which centers near the junction of the boundary lines of New Mexico, Arizona, Sonora, and Chihuahua.

Scientific knowledge of New Mexican mammals begin with S. H. Long's expedition to the Rocky Mountains in 1820, when the party passed through northeastern New Mexico. Various naturalists made trips into or through the State, frequently in connection with military expeditions, during the next 70 years. Beginning in about 1889, biologists from the United States Bureau of Biological Survey (predecessor agency of the Fish and Wildlife Service), most important of whom was Vernon Bailey, collected and studied mammals in the State. This work was intensive from 1889 to 1924. The results of studies to 1924 were published in 1932 as North American Fauna No. 53, *Mammals of New Mexico* by Vernon Bailey.

Since Bailey's time, knowledge of taxonomy and distribution of western mammals has undergone revolutionary changes. These changes have been summarized in a new work on the *Mammals of New Mexico* compiled by two Fish and Wildlife Service research biologists and university cooperators. The study summarized the exami-



Research at the National Fish and Wildlife Laboratory includes the collection of voucher specimens from areas where the fauna is poorly known. These specimens are deposited in the National Museum of Natural History, where they are available for a variety of studies. (Photo courtesy Smithsonian Institution)

nation of 37,000 mammals from the State of New Mexico. Included is material on geographic and habitat distribution, taxonomic problems, and biogeographical generalizations.

Studies on Neotropical cricetine rodents.—Most field biologists are acquainted with the numbers and variety of North American cricetine rodents, particularly the deer mice, woodrats, and the harvest mice. These rodents, numbering some 12 genera and approximately 100 species, comprise a natural assemblage (Nearctic) distinguishable from their Neotropical counterparts in possessing a simple baculum (penis bone). But few biologists know anything of the Neotropical cricetine rodents characterized by a complex baculum; this group numbers at least 50 genera and over 300 species. Members of the group that occur in the United States are rice rats and cotton rats.

With few exceptions, the ecology, distribution, life history, and taxonomic identity of Neotropical crictines are

virtually unknown. At the National Fish and Wildlife Laboratory, research on the rice rats is attempting to clarify the species identities and relationships within this group of rodents. Data have been gathered from rodent populations in the United States, Mexico, Costa Rica, Panama, Colombia, and Peru. These studies, principally based on the karyotypic analysis of field-prepared chromosomal material, have clarified the taxonomic identities of some species of oryzomyine rodents and have resulted in a new phylogenetic interpretation of the inter- and intra-group relationships of Neotropical crictines. Although these studies are directed at broader scientific problems, the immediate results could have a major effect on the study and control of sylvan rodent hosts and vectors of a variety of diseases important in tropical medicine because the taxonomic determination of many of the rodent species analysed in previous studies was wrong.

Status of raccoons in Florida.—Increasing land development in and near coastal areas in the southeastern



Cooperation with officials and natives of foreign countries is essential to conduct research there. Here a National Fish and Wildlife Laboratory employee demonstrates his scientific skills for an interested audience. (Photo courtesy Smithsonian Institution)

United States has necessitated evaluation of the animals of the coastal ecosystem. Of special interest are those that exhibit unique adaptations to a particular place or mode of living. Many such animals occur in peninsular Florida and on the Florida Keys, and they are coming into increasing contact with man and his environmental changes. A study, focused on the raccoons of Florida, is designed to evaluate the uniqueness of the various Florida populations, and, potentially, to monitor changes in these raccoons or their distributions resulting from man's activities. Findings indicate that the raccoons occurring on the middle and outer Keys are unique morphologically and are most closely related to a disjunct population now living in the Ten Thousand Island area of southwestern Florida. These two groups of raccoons probably invaded the Keys several thousand years ago when the sea level was lower, and they were isolated thereafter until man built bridges between the Keys. The raccoons from the upper Keys are more similar to mainland raccoons from southeastern Florida and represent a more recent invasion. Although raccoons often profit individually from man's activities it seems likely that the Florida Key raccoons will ultimately lose their unique genetic integrity by interbreeding with raccoons invading from the mainland along the bridges and roads constructed by man.

Abundance and trends of the marine otter.—Darwin reported that this otter was abundant in the Chonos Archipelago and among the islands off the southwestern shores of Tierra del Fuego. It has been greatly diminished in numbers since Darwin's time, but in 1923 the Chicago Field Museum's expedition found it to be common along the southern end of Chiloe Island, Chile. Nothing is

known about numbers of the marine otter along the northern coast of Chile, but in Peruvian waters the population is estimated to be between 200 and 300. In the Cape Horn and southern Tierra del Fuego regions this species has been practically exterminated. One specimen was collected at Wollaston Islands, Tierra del Fuego, about 25 years ago.

Regulations regarding polar bears.—In the past, polar bear harvests in Alaska were limited by bag limits, a permit system, a limit on the number of hunts in which individual guides could participate, and protection for young and females with young. Two management areas were established for Alaska, one to the west and one to the north. Residents were allowed to hunt bears at any time for food provided aircraft were not used. Hides and skulls of all bears taken had to be submitted to the Alaska Department of Fish and Game within 30 days for examination, sealing, and removal of a tooth for age determination. Alaska banned the use of aircraft for hunting polar bears after 1 July 1972 and lengthened the season to encourage sport hunting from the ground.

The Federal Marine Mammal Protection Act of 1972 transferred management authority for polar bears to the Federal government and limited their harvest to Alaskan coastal Eskimos for subsistence or for manufacture of traditional native articles of clothing or handicraft. The Marine Mammal Act removed restrictions on harvest of young and females with young by natives. The request by the State of Alaska for return of management authority for polar bears and certain other marine mammals, as provided for in the Marine Mammal Act, is under review. Regulations to implement the Act require that tanneries be registered before they can tan skins of bears taken by natives. None have yet been registered. Natives are tanning skins of young bears at home and making clothing for their own use and for sale. Skins of older bears must be tanned commercially before they can be used for garments, and because no tanneries have yet been registered, skins from older bears are being wasted.

The U.S.S.R. has not allowed hunting of polar bears since 1956. Norway stopped set gun and trophy hunting in 1971 and enacted a 5-year moratorium in 1973 on all harvesting because studies indicated that the bear population was smaller than previously believed. In Greenland only Eskimos or long-term residents may take bears and they must use traditional ground methods of hunting. In Canada, prior to 1968, Eskimos hunting from the ground took bears with few restrictions. Since then, harvests have been regulated by establishment of hunting districts with quotas. In certain districts, trophy hunters may purchase a permit to take a bear from its quota provided a native resident is used as a guide.



Female polar bear with cub. Research and management of polar bears is being coordinated among five nations, Canada, Denmark, Norway, Russia, and the United States. An agreement for conservation of the species has been drafted by biologists of these nations. (Photo by J. W. Lentfer)

In November 1973, the five polar bear nations—Canada, Denmark, Norway, Russia, and United States—drafted an Agreement on Conservation of Polar Bears to allow bears to be taken only in areas where traditional means have been used in the past, and to prohibit use of aircraft and large motorized vessels as an aid in the process. Also, the agreement calls for both national and cooperative international research and management, especially on populations occurring on the high seas or within more than one national jurisdiction; provides protection for ecosystems of which polar bears are a part; by resolution, seeks special protection from hunting for denning females, females with cubs, and cubs; and, by resolution, asks for an international system of hide identification to better control traffic in hides. In Alaska, the agreement would allow the same type of management program that the State had in effect immediately preceding the Marine Mammal Act. The agreement

becomes effective when ratified by three of the five nations. Canada and Norway have ratified it. In the United States the Director of the Fish and Wildlife Service, on the basis of an Environmental Assessment, has made a Negative Declaration stating that an Environmental Impact Statement is not required for the State Department to present the agreement to Congress for ratification.

Washington, D. C., Office

Wildlife importation into the United States.—The pattern of wildlife importation into the United States has dramatically changed during this century. The number of birds imported annually in recent years is only slightly greater than the total reached in the peak years before the economic depression of the 1930's. More than twice as many canaries were imported in early years as in the recent years of 1968-72. Until 1940 game birds accounted

for about one-third of the imports, but very few were brought in during the recent period. Parrots and other cage birds were imported in much greater number in 1968-72 than in 1901-42. More parrots were imported in the recent 5-year period than in 27 earlier years for which data are available, and there has been a shift from the budgerigar (an Australian parakeet) to other species.

During each of the years 1968-72, the annual importation of mammals was greater by at least a factor of 5 than in the earlier peak year of 1938. In a recent 5-year period,

more than twice as many mammals were imported than in 1901-42. Guinea pigs and laboratory mice for experimental purposes and silver and cross foxes for fur farms were the most important mammalian imports early in the century, but primates—especially squirrel monkeys and rhesus macaques—were the main imports in 1968-72. No data on imported reptiles or amphibians are available for the early part of the century, but more than 2 million individuals in both groups were imported in the years 1970 and 1971.

RESERVOIR FISHERIES

National Reservoir Research Program

A long-term fishery research program on large reservoirs was established by the Fish and Wildlife Service in 1963 in response to requests from many public and private agencies. Construction of Federal impoundments has created fishery management problems which most State agencies are unable to attack single-handedly. The widely recognized need for intensive ecological research is being met through concentrated field study of four types of reservoirs that differ greatly in environmental and operational characteristics, plus analysis of all of the information available nationwide on fish standing crop and angler harvests. The effort is yielding results that are broadly applicable, as well as specific findings that are useful to the State agencies charged with managing the particular reservoirs under study.

By the year 2000, reservoir angling pressure is expected to double. Reservoir construction has slowed and fishery management methods must be improved if the predicted increase in angling activity is to be satisfied. Expanding sport fishery resources in these man-made lakes is a major research goal of the Fish and Wildlife Service, working in concert with other Federal agencies, State agencies, and academic and private institutions.

The National Reservoir Research Program, headquartered in Fayetteville, Ark., provides administrative coordination of the field research units and conducts a nationwide analysis of the effects of reservoir environmental and operational factors on fish production and yield. Correlation and multiple regression statistical techniques have been used to test the effects of environmental variables on fish standing crop, angler use and harvest, and commercial fishing yields.

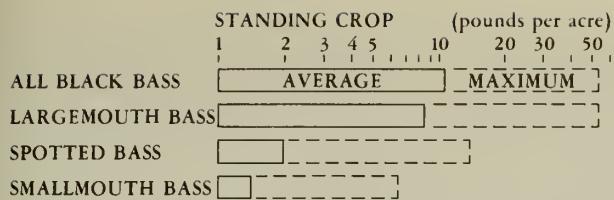
Predator fish stocking evaluation.—Data resulting from a coordinated 2-year study of 26 reservoirs in 11 southern States where stocking of striped bass, walleyes, or rainbow trout has been an important management practice, have been assembled by the National Reservoir Re-

search Program. Member agencies of the Reservoir Committee, Southern Division, American Fisheries Society, participated in the simultaneous collection of data on selected environmental variables, fish standing crop, and angler harvest in an effort to identify factors that influence success of the introduced predators, and to gain new insights into predator-prey relations.

Data were collated and prepared for computer analysis and computer printouts supplied to participating agencies. Regression analyses of environmental factors vs. fish standing crop were completed and a program was developed for calculation of the biomass of prey available for any given size of predator, based on mouth size and prey body shape. On the basis of weight-frequency data from samples collected in coves in August, the program provides an estimate of the adequacy of the prey food base for the remainder of the growing season and clues as to the advisability of stocking additional predators.

Reservoir black basses.—In a paper presented at a national bass symposium in February, black bass populations were reported in about 1,300 United States reservoirs larger than 500 acres, totaling 7 million acres. On the basis of samples collected in coves of 173 reservoirs, the average summer standing crop of bass (in pounds per acre) was estimated to be: largemouth, 8.9; spotted, 2.0; and smallmouth, 1.4. Predatory sport fishes typically make up about 15% of the total standing crop, and these three basses make up about one-third of that predator crop.

Correlation analyses indicate that crops of largemouth bass are positively influenced by length of growing season, dissolved solids content of the water, and depth of the dam outlet. Spotted bass crops are highest in deeper, younger, less fertile reservoirs; smallmouth bass crops are highest in the older, larger, fluctuating reservoirs that are less fertile and have shorter growing seasons. Interspecific correlations showed that largemouth bass crops are positively related to those of spotted bass, and that both



Average and maximum standing crops of black basses in southern reservoirs (on logarithmic scale).

are negatively related to crops of smallmouth bass. Largemouth bass crops are positively linked with those of other predators such as crappies, white bass, spotted gar, and chain pickerel, but negatively with crops of longnose gar. Spotted bass crops are not correlated with crops of those predators, but are positively linked with walleye and grass pickerel crops. Smallmouth bass crops are negatively related to those of crappies, longnose gars, and blue and flathead catfishes, and are positively related only to crops of rainbow trout, redhorse, and spotted suckers.

A simplified model of a typical reservoir fish population portrays a minimum crop per acre of 25 pounds of predators (including 8 pounds of black bass), 75 pounds of plankton-feeders, and 100 pounds of bottom-feeders. Reservoir species complexes are intermediate in character between river and lake fish populations. The upper portions of many reservoirs are river-like and the lower parts lake-like, and the fish populations present usually reflect these habitat differences.

Controlled water level fluctuation is the most promising management technique for increasing largemouth bass production. Reduction of rough fish and shad should enhance smallmouth and spotted bass production. Mathematical models that include all the important ecological factors affecting bass are being developed so that the results of management manipulations can be accurately predicted.

North Central Reservoir Investigations

Water management affects fish population in a Missouri River reservoir.—Recently completed studies on Lewis and Clark Lake, a 28,000-acre main stem Missouri River reservoir on the border of South Dakota and Nebraska, show how water management can affect a fish population. The reservoir, completed in 1955, is managed by the U.S. Army Corps of Engineers for flood control, hydroelectric power, navigation, irrigation, and other purposes.

Investigations were conducted in 1956-74 to document development of the fish population, to explain the causes of changes over time, and to suggest management measures that might increase abundance of desirable species.

These studies were undertaken because fish in new reservoirs have usually been abundant for the first few years after impoundment, but then have declined in both species numbers and general abundance.

Annual sampling of the fish population of Lewis and Clark Lake with various types of capture gear showed that fish abundance near the end of the study was only about one-third that during the early years; about one-fifth of the species were lost or became rare. Changes in the population were the result of poor fish reproduction and lack of recruitment to adult stocks, caused by water management and related shoreline modification. Low and fluctuating water levels during May and June were detrimental to fish spawning and survival of young. The water exchange rate, or the length of time it takes water to move through the reservoir, decreased from 10 days during the early years of impoundment to 4-5 days in 1969-72. The high rate of water exchange was harmful to the fish population, partly because large numbers of young fish were lost in the reservoir discharge. Erosion of shorelines and deposition of silt in the reservoir headwaters eliminated many areas formerly used for fish spawning.

With the present schedule of water management, the fish population of Lewis and Clark Lake is expected to be dominated by species which are not dependent on near-shore areas for reproduction: saugers, channel catfish, and freshwater drum. River carpsuckers will probably also remain common because they apparently move into the reservoir from the river upstream. White bass, emerald shiners, and especially white crappies are likely to be only moderately abundant because spawning habitat is limited and survival of young is low. The abundance of fish could be increased if high water levels were maintained during May and June. This is not possible because of the flood control function of the reservoir.

The major benefit of Lewis and Clark Lake to sport fishing is its contribution to the fishery in the tailwater below the dam. This location is one of the most popular fishing areas in the Missouri River reservoir system. Angler success in the tailwater has improved since 1970, following high water releases from Lewis and Clark Lake during the summers of 1969-72. Recruitment to tailwater fish stocks is partly from the reservoir. Fish concentrate in the tailwater because food is abundant and some of the species spawn in the area.

Fish population assessment valuable.—Fishes in the four lower main stem Missouri River reservoirs in North and South Dakota have been investigated annually since the lakes were constructed in the 1950's and 1960's. Studies of long-term abundance trends and species life histories by biologists of the North Central Reservoir Investigations have demonstrated that changes (abundance, reproduction, growth, mortality) in the fish stocks

with time provide a reliable measure of how fish respond to various types of water management and environmental conditions.

Planners and developers are looking to the Missouri River reservoir system to provide the great quantities of water needed for large-scale irrigation projects now under construction in the Dakotas, for increased peaking hydroelectric power from the main stem dams, and for energy development from the vast stores of coal in the Northern Great Plains. The long-term biological data collected on these reservoirs will provide information needed to evaluate the effects on the reservoir environments of the proposed changes in water management or modification of water uses.

Shoreline development and fish species change in Missouri River main stem reservoirs.—Shore erosion has had significant effects on the fish populations of the Missouri River main stem reservoirs; this natural process has not been adequately considered in reservoir planning. Shorelines of these reservoirs undergo at least four major, virtually irreversible changes during the first 20-25 years of impoundment: (1) small embayments become lost due to the building up of barrier beaches by wave action and current; (2) headlands become rounded and lose their diversity; (3) shorelines slopes lose much diversity due to the filling in of depressions and the eroding of ridges; and (4) most stabilized shores are not suitable for the growth of vegetation. Most of the shores along these reservoirs consist of geologically young sedimentary shales and clays; these deposits erode rapidly when exposed to heavy wave action and fluctuating water levels. Exposed glacial till, however, resists erosion and forms a firm, armored shoreline.

Shore erosion has influenced fish populations primarily by decreasing or increasing the amount of spawning and nursery habitat of individual fish species. The general effects of this development on the abundance of 16 common fish species may be summarized as follows: (1) adversely affected—white crappie, black crappie, gizzard shad, bigmouth buffalo, smallmouth buffalo, yellow perch, and northern pike; (2) moderately affected—emerald shiner, river carpsucker, and carp; (3) least affected—sauger, white bass, goldeye, channel catfish, and freshwater drum; and (4) benefited—walleye. The species moderately or least affected by shore development reproduce in tributary streams, the unimpounded Missouri River, or in open water. The walleye has benefited because of the exposure of glacial till along shores. Growth rates of all predator fish have decreased in recent years because of the low abundance of forage fishes—yellow perch and emerald shiners. The reduction of embayment habitat and loss of vegetation were the primary causes of fish population change.

Shoreline erosion and redeposition processes should be viewed early in reservoir planning when large bodies of water are being contemplated on erodible soils like those in the Northern Great Plains. With knowledge of the natural erosion processes, plus the effects of wave action and water level fluctuation, one could extrapolate the probable shore configuration and slope and judge the probable effects on various fish species. It would then be possible to integrate mitigation measures into reservoir planning that would benefit fish species which would otherwise probably decline because of shore modification.

Aerial creel census used on South Dakota reservoir.—A year-long creel census was recently completed on Lake Sharpe, a 56,000-acre main stem Missouri River reservoir in South Dakota. The objectives of the study, carried out by the South Dakota Cooperative Fishery Research Unit, were to develop, implement, and evaluate an aerial creel survey for a large reservoir with many points of access. Obtaining accurate information on sport fishing pressure and harvest has always been a problem for fishery management agencies. The problem is compounded as the size of the water under investigation increases, and is most difficult on large, open reservoirs which are now common in all of the major river systems in the United States.

Fishing pressure was estimated by aerial counts of fishermen, and catch rates, mean party size, mean fisherman day, and residence of the anglers were determined by an angler interview survey. The two surveys were combined to estimate harvest. Estimated fishing pressure on Lake Sharpe and its tailwater was 340,131 fisherman-hours and estimated total harvest was 113,800 fish weighing 162,000 pounds. The mean catch rate was 0.33 fish per fisherman-hour. Walleyes made up 82% of the total number of fish and 76% of the total weight.

The survey, with a relatively small amount of manpower, yielded estimates of catch statistics that were well within the accuracy needed for management decisions. The methods used may be applicable to many other large, open reservoirs with numerous access points.

Changes in young-of-the-year fish stocks in Lake Oahe.—The impoundment of Lake Oahe, a large storage reservoir on the upper Missouri River in North and South Dakota, created much interest in its potential fish production. The establishment of a base for estimating this potential required that the composition and abundance of the fish stocks be assessed. The annual production of young fish was of primary interest because the fate of these fish would determine trends in the composition and abundance of the adults. After exploratory work in 1964-65, young of the year were sampled with a beach seine during the final years of filling (1966-69) and early years of full impoundment (1970-74).



Walleyes are the most abundant sport fish in the Missouri River main stem reservoirs. (Photo by C. Post, South Dakota Department of Game, Fish and Parks)

Although 41 species were caught in the seine, six species (yellow perch, emerald shiners, white crappies, black crappies, white bass, and bigmouth buffalo) accounted for 93% of the total. About one-third of the species reported in this stretch of the Missouri River before impoundment of Lake Oahe have disappeared; some have been replaced by other species, although total species number has decreased since the reservoir has filled.

Average general abundance of young-of-the-year fishes increased during filling, peaked in 1968, and declined thereafter; abundance in 1974 was less than one-twelfth that of the peak year. The reduction primarily reflected a decrease in species that normally require or use flooded, vegetated grounds for spawning and nursery areas; these included mostly forage fishes, such as yellow

perch, black bullheads, and various species of minnows. The abundance of the principal predatory sport fishes (walleyes, saugers, and white bass) has remained relatively stable since the reservoir filled, but that of commercial fishes (goldeye, buffalos, carp, and river carpsuckers) has decreased. Thus prospects for the sport fishery continue to be good, whereas the potential value of the commercial fishery appears to be limited. Generalized deterioration of spawning and nursery areas through erosion, sedimentation, and loss of vegetation was mainly responsible for the decline in species numbers and abundance of the young of the year, and it is doubtful that the deterioration of such areas will be alleviated in the foreseeable future.

Tributary streams important for fish spawning in main stem Missouri River reservoirs.—Studies begun in 1971

were directed toward locating the spawning and nursery areas of common fishes in Lake Oahe. Preliminary sampling was conducted throughout the reservoir, but since 1972 the work has been concentrated in the three major tributary rivers—the Cheyenne, Moreau, and Grand—and their embayments.

The rivers proper have proved to be of greater importance as spawning areas than was previously realized. Goldeyes, walleyes, saugers, channel catfish, and probably river carpsuckers spawn exclusively in river habitat; yellow perch and crappies are the only species that spawn exclusively in the reservoir portion. Carp, buffalos, white bass, and freshwater drum spawn in both areas, though the upper sections of the embayments are the most important.

Eggs and larvae of the river-spawning species have been taken 65 miles upstream from the reservoir, the farthest upstream sampling site. The upstream limit of their spawning grounds has not yet been determined. The larvae of most river-spawning species are carried downstream by the current to the embayments. They use the upper ends of the embayments as nursery areas, and tend to migrate downstream toward the main reservoir as the summer progresses.

Reproductive success of river-spawning species appears to depend primarily on the volume of river flow. Correlation of river flows with observed reproductive success, for example, explains more than 90% of the annual variation in the number of goldeyes produced, and 60% of the number of walleyes produced. During the last 10 years, the higher the river flows, the higher the reproductive success has been.

South Central Reservoir Investigations

Biologists of the South Central Reservoir Investigations, headquartered in Fayetteville, Ark., conduct research on biological and physiochemical factors that influence the sport fisheries in White River reservoirs—Beaver Lake (11,420 ha) and Bull Shoals Lake (18,400 ha)—in Arkansas and Missouri.

High runoff and unusually high water levels continued in 1974. Although the effects were not as pronounced as in 1973, a year of near-record flooding, rates of hypolimnial oxygen depletion were somewhat more rapid than during drier years, and conductivity and transparency in both Beaver and Bull Shoals lakes were low. The spring peaks of zooplankton abundance were also more protracted than during drier years.

Plankton distribution and biomass.—A detailed study of vertical zooplankton distribution was completed on Beaver Lake, and analyses are being made to relate this distribution pattern to a number of regularly monitored physiochemical variables. Work on methods for separat-



Retrieving a Miller sampler. Metered tow net samples are used to obtain estimates of seasonal zooplankton abundance on White River impoundments. (Photo by L. Barger)

ing zooplankton from algae and detritus in tow net samples was also completed. The method which has proved most effective, although time-consuming, involves separation by centrifugation through a series of sucrose gradients.

Underwater observations of black bass reproduction.—Studies of the spawning requirements and reproductive potential of largemouth, smallmouth, and spotted bass were continued in Bull Shoals Lake during 1975. Underwater observations were conducted weekly in five study areas from 28 April through 4 June. High water levels early in the spawning season flooded the bases of shoreline willow trees to a depth of about 2 m, providing nest cover in cove habitats used by largemouth and spotted bass. Nests of both species were most frequently found beside the bases of willows, and nest substrate usually included small roots and root hairs. Smallmouth bass continued to nest in areas of gently sloping bottoms and over rock and gravel substrates. Moderate numbers of all three species also nested along a steeply sloping shoreline habitat, as they have in previous years when water levels were near normal. Mean respective nest



A male smallmouth bass guarding a nest with eggs. Rock and gravel is the type of substrate most often used for nesting by this species in Bull Shoals Reservoir. (Photo by L. Vogele)

depths in this habitat for largemouth, smallmouth, and spotted bass were 2.5, 2.2, and 3.0 m, as compared with 1.4, 2.7, and 1.4 m in the coves.

The spawning season for black basses began relatively late (about April 24)—nearly a week later than the mean date of first spawning observed during the previous 9 years. Water temperatures, which had been lower than usual, began rising rapidly about 21 April and increased more than 11°C in 22 days. The effect of this late but rapid warming was to concentrate the spawning season into a relatively short period of time, and to shorten egg incubation and larval development periods. The numbers of nests relative to the numbers of resulting fry schools indicated the highest rate of survival to swim-up stage yet observed. However, nest densities were extremely low,

water levels were receding, and water transparency was increasing during the spawning season. The decreasing water levels left little vegetative cover available late in the spawning season, and the increasing water transparency left the fry schools highly vulnerable to predators. The fry schools appeared to have suffered heavy mortalities by the first week of June; most fry were dispersed in small groups along the bottom, although the size of the fish was closely similar to that of the bass in the few remaining large schools.

Food and survival of young largemouth and spotted bass.—Inasmuch as patterns of early growth and ultimate year-class strength of largemouth and spotted bass are closely related to the availability of certain vertebrate and nonvertebrate food sources, work on the development of

sampling methods was begun in 1974 to better quantify these relations on Beaver Lake. Gear for simultaneously sampling zooplankton and larval fish was developed, as were methods for frequently assessing the abundance of young largemouth and spotted bass. Food studies indicated different rates of survival between young largemouth and spotted bass, and differences in growth related to feeding behavior. The program was expanded during the spring of 1975 to include interrelations between young prey fish species and zooplankton and bottom organisms.

Abundance of black basses estimated by electrofishing.—Annual estimates of black basses in Beaver and Bull Shoals lakes provide a means of assessing long-term mortality and production rates and evaluating the effects of angler harvest. Mark and recapture estimates along selected sections of shoreline in the spring in Beaver Lake yielded an estimated largemouth bass population of 115 fish per kilometer of shoreline in the lower section of the reservoir and 155 per kilometer in the mid-lake section. Although a reliable estimate was not obtained for spotted bass, there has been a definite increase in numbers in the past few years.

In Bull Shoals Lake, estimates of largemouth bass abundance were 626 per kilometer of shoreline in the lower section and 448 per kilometer in the upper section. Reliable estimates of spotted bass or smallmouth bass were not obtained in either section. The 1974 estimates for largemouth bass were 15 times higher than the estimates for 1973 because of the recruitment of the large 1973 year class. The 1974 spring estimate was about half that of fall 1973, suggesting that natural winter mortality of the 1973 year class was high.

Black bass population estimates from fishing tournament catches.—Largemouth bass population estimates were made in conjunction with Bass Anglers Sportsmen Society tournaments on Beaver Lake in April 1974 and in Bull Shoals Lake in April 1975. Bass 305 mm (12 inches) long or longer (total length) were captured by the use of electrofishing gear, tagged, and released before the tournaments, and tournament catches were used as recapture samples. The Bull Shoals tournament was supplemented with a 4-week posttournament creel census in the spring for the lower reaches of both lakes. Both estimates were considered low for the lakes as a whole because creel data indicate a much higher density of bass in the upper reaches of both lakes. An inability to randomize marks and recaptures lakewide was considered the probable source of error. It was concluded that sufficient numbers of fish can be handled by these methods to permit valid population estimates, once the problems of randomizing marks and recaptures are overcome.

Feeding ecology of larval shad.—In a study of the food of larval shad and the relation of feeding to plankton densities, it was determined that small shad tend to select the larger zooplankton, but then select smaller zooplankters as the fish become larger. The possibility of competition for food exists between species, and massive mortalities of larval shad may result from starvation.

Anglers' harvest.—After 3 years of nearly stable fishing effort and harvest, the sport fishery in Bull Shoals Lake improved sharply during 1974. Harvest of sport fish exceeded that of the three previous years combined, and fishing effort nearly doubled. This increase was caused primarily by the recruitment of exceptionally strong year classes of several sport fish species in 1973. Production of these strong year classes occurred during a period of near-record flooding, which suggests that the resulting increase in nutrients may have played a dominant role in determining the success of the year class.

A more modest increase in the harvest of sport fish occurred in Beaver Lake during this period. Compared with 1973, fishing effort in 1974 increased by about 25% and sport fish harvest by more than 50%. The relatively small flood pool of Beaver Lake and higher turbidity of the water may have been responsible for the apparent lesser response of fish in this lake to periods of flooding.

National symposium on the biology and management of centrarchid basses.—South Central Reservoir Investigations personnel participated in a National bass symposium held at Tulsa, Okla., in February 1975. The four papers presented concerned a review of the spotted bass, the relation of certain physical and biological variables to black bass, crops in Beaver and Bull Shoals lakes, production of largemouth bass, and effects of food and cover on year-class strength of largemouth bass in Bull Shoals Lake. An underwater movie on the reproductive behavior of spotted bass was shown as a part of the program.

Southeast Reservoir Investigations

Purpose of the studies.—As demands for electrical energy continue to grow, the number of fossil and nuclear fueled steam-electrical generating stations also increases. About three-fifths of the energy produced from burning fossil fuels and two-thirds of the energy from the nuclear fission process at steam-electrical generating stations is absorbed by condenser cooling water and is carried into the nation's waterways. To meet peak power requirements, electric power companies are building an increasing number of pumped storage hydroelectrical projects. Pumped storage installations have reversible pump-turbines that generate electricity during hours of peak electrical use; during hours of low demand, water is pumped back into the reservoir for re-use in generating



Duke Power Company's Oconee Nuclear Plant on Keowee Reservoir. About three-fifths of the energy produced from burning fossil fuels and two-thirds of that from the nuclear fission process at steam electrical generating stations are absorbed by condenser cooling water which is frequently discharged into the Nation's waterways. The Fish and Wildlife Service is conducting research to determine the effect of thermal additions to the aquatic environment (Southeast Reservoir Investigations photo)

power.

Under the Fish and Wildlife Coordination Act, the Fish and Wildlife Service reviews water resource development projects and makes recommendations to prevent loss or damage to fishery resources. The data on which sound recommendations are based must be gathered by research. Southeast Reservoir Investigations was established to determine the effects of the waste cooling water from Duke Power Company's Oconee Nuclear Station, and operation of the Jocassee pumped storage installation, on the fishes of Keowee and Jocassee Reservoirs in western South Carolina. Information gathered on this system should help biologists predict the effects that other proposed developments might have on fishery resources.

Unit 1 of Oconee Nuclear Station began operation in May 1973, Unit 2 in December 1973, and Unit 3 in September 1974. Power production averaged about 20% of rated capacity in late 1973 and about 40% during 1974. Condenser cooling water from the south arm of Keowee Reservoir is drawn beneath a skimmer wall which was constructed from above the lake surface down to a water depth of 19.8 m. After passing through the power plant condensers, the water is discharged back into the north arm of Keowee Reservoir at a depth of 10.7 m.

The four turbines in Jocassee Dam are reversible and can be used to pump water from Keowee Reservoir back

into Jocassee Reservoir. During the pumping cycle, water is drawn at a rate of 6,200 cubic feet per second per turbine from Keowee at a depth of about 19 m. The first pump-turbine began operation in December 1973 and operated intermittently during 1974. All four units were operable by 1 May 1975.

Limnology of Keowee Reservoir.—Limnological data collected during 1971 and 1972 indicated that Keowee Reservoir is a warmwater lake which becomes thermally stratified in summer and has one circulation period each year during fall and winter. The reservoir began warming in March; stratification began developing in May and was completed in June. The top of the thermocline was at a depth of 3 to 8 m in June and July but began to move downward in late August when the fall cooling period began. The top of the thermocline reached a maximum depth of 15 m in October, and by December the temperature was nearly uniform from surface to bottom. The reservoir continued to cool to a low near 8°C in February.

Average annual temperature at a depth of 1 m in Keowee Reservoir was 19.3°C in 1973-74 and 18.2°C in 1971-72. Water temperatures at 1 m in 1974, compared with those in 1971-72, were higher in fall and winter, but lower in spring and about the same during summer. November water temperatures were 3.7°C higher in 1973 and 5.7°C higher in 1974 than in 1971-72. On 19 March

1975, surface water temperatures were 2° C above ambient 4 miles from the discharge of Oconee Nuclear Station in Keowee River arm, and more than a mile from the discharge into the Little River arm. From May through August 1974, water drawn under the skimmer wall was so cool that, even though it was warmed an average of 4.6° C while passing through the condensers, its temperature as it left the condensers was lower than that of the reservoir surface. Thus the effluent, which was injected into Keowee Reservoir at a depth of about 10.5 m, did not rise to the surface. Withdrawing cooler water from the deeper portion of Keowee Reservoir, warming it, and returning it below the surface warmed the hypolimnetic waters during summer. In 1973, with limited operation of Oconee Nuclear Station beginning in May, higher water temperatures at 20 m were first noticeable in August and were 5.5 and 6.5° C higher in September and October than during the same months of 1971-72. At the 20-m depth, warming began in April in both 1974 and 1975. In September 1974, mean water temperature at 20 m was 21.5° C, compared with 10.6° C in 1971-72. The annual average temperature at 20 m was 15.1° C in 1974, compared with 9.7° C in 1971-72.

Average water temperatures of Keowee Reservoir, weighted by volume in each depth stratum, increased in the summer and fall due to the warmer hypolimnetic water. Mean reservoir temperature became noticeably higher in May 1974 and 1975 than in 1971-72, and in 1974 the warming continued until September. During September, October, and November 1974, the average temperature of Keowee Reservoir was more than 5° C higher than that for the same months of 1971-72. Annual mean temperature of Keowee Reservoir for 1974 (16.9° C) was 3.3° C higher than the 1971-72 average (13.6° C). Some differences in reservoir temperature from year to year due to normal variation in meteorological conditions is expected, and warmer water in 1974 may be attributable in part to natural causes. However, annual average air temperature at the Clemson University weather station was 1.3° F lower in 1974 than in 1971 and 0.8° F lower than in 1972. It appears, therefore, that part of the heat from the Oconee Nuclear Station condenser cooling water is stored in the deeper portions of Keowee Reservoir from April to September. During the fall the entire reservoir cools, but the stored heat prolongs the cooling process and results in higher water temperatures at all depths.

Biology of Keowee Reservoir.—Some 53 species of copepods and cladocerans and 100 species of macroinvertebrates have been collected in Keowee Reservoir since sampling began in July 1973. Abundance of zooplankton was highest in spring and lowest in late summer and fall. Average density of zooplankton near Oconee Nuclear Plant was about half that found in areas most distant from

the power plant. The dominant benthic invertebrates are chironomids and oligochaetes. In the area near Oconee Nuclear Station, abundance of chironomids was half and abundance of oligochaetes was double that in the other areas of the reservoir.

During the first few years after impoundment of a reservoir, the fish populations usually undergo considerable changes in response to the environmental conditions which are created in a new reservoir. Keowee Reservoir was impounded in four stages from May 1968 to April 1971. Identification of changes in the fish population, which were occurring in response to the changing reservoir environment, will later serve as a basis for determining whether further changes occur as a result of operation of Oconee Nuclear Station and the Jocassee pump storage facility.

Biologists of the South Carolina Wildlife and Marine Resources Department sampled the fish populations in 1968-71 and biologists of the Southeast Reservoir Investigations have sampled them since 1972, using a variety of methods. Of the 40 species of fish that have been collected in Keowee Reservoir, 14 were stream-type species that occurred mostly during the 1st year after impoundment. Only two stream-type fish, quillback and silver redhorse, were present in significant numbers in 1974, and only as adults. A few riverine fishes will probably continue to enter the reservoir from tributaries. The other 12 species have been found occasionally in small numbers, but do not appear to be reproducing in the reservoir.

Four species reproduced in large numbers only during 1 or 2 years as Keowee Reservoir filled. Carp reproduced only in 1968 but continued to dominate the population biomass in 1975. Chain pickerel reproduced significantly only in 1970, brown bullheads in 1968 and 1970, and golden shiners only before 1970. Only a few large chain pickerel, brown bullheads, and golden shiners were collected in 1974.

Ten species have reproduced in significant numbers since Keowee Reservoir completed filling in 1971. Largemouth bass, black crappies, and flat bullheads, which produced their strongest year classes in the 1st or 2nd year following impoundment, have continued to reproduce each year. Yellow perch reproduction was limited until 1973 and 1974, when large numbers of young were produced. Redbreast sunfish, green sunfish, warmouth, and bluegills have reproduced successfully each year. The bluegill is by far the most abundant and the green sunfish the least abundant of these four sunfishes. The whitefin shiner has become one of the most abundant small fish along the shoreline and has been reproducing each year. Threadfin shad, stocked in Keowee Reservoir in January 1974 by the South Carolina Wildlife and Marine Resources Department, reproduced successfully

in 1974.

Largemouth bass, black crappies, yellow perch, and bluegills have been selected for intensive study in Keowee Reservoir. Information on growth, food, success of re-

production, and survival before operation of the nuclear power plant and pumped storage facility has been collected as a basis for determining whether significant changes occur as a result of power plant operation.

COOPERATIVE RESEARCH UNIT PROGRAM

The Cooperative Research Unit Program is a cooperative endeavor supported by the U.S. Fish and Wildlife Service, State game and fish agencies, and land grant colleges and universities. The Wildlife Management Institute is an additional cooperator for the Wildlife Units. The Program began with the activation of the Iowa Wildlife Unit in September 1935. The Fishery Units began at Utah State University in 1962. Twenty-five Fishery Units have been in operation since 1971 and 20 Wildlife Units since 1972. In 1973 the two unit Programs were merged into one, administered by the Division of Cooperative Research.

The objectives of the Cooperative Unit Program, in order of priority, are fish and wildlife research, training at the graduate level, and extension service. Program direction at each Unit is provided by a Coordinating Committee composed of representatives from the cooperating State game and fish agency, the cooperating university, and the U.S. Fish and Wildlife Service. The Committee sets the research direction and plans the long-term program to serve the mutual needs of the cooperators. Day-to-day operation is the responsibility of the Unit Leader and the Assistant Unit Leader, who are employees of the U.S. Fish and Wildlife Service. The cooperating university provides expertise in related scientific fields; office, laboratory, and storage space; secretarial service; and utilities. All cooperators contribute funds and equipment to the unit, and additional research funds are obtained from various sources as grants and contracts. The leader and assistant leader are extended full faculty status and are, therefore, responsible for advising and directing graduate students and available for teaching formal courses and conducting seminars. In the field of extension, unit personnel organize and participate in workshops and training meetings and provide technical fish and wildlife expertise as needed. Each year unit personnel publish many technical and general papers on fish, wildlife, and related subjects.

During the fiscal and academic year 1974-75, personnel of the Fishery Units conducted 312 research studies, 94 of which were completed. Personnel of the Wildlife Units carried out 301 studies, of which 87 were completed. These studies and other activities resulted in

144 technical and general papers from the Fishery Units, and 185 from the Wildlife Units. Papers presented at meetings totaled 102 for the Fishery Units and 77 for the Wildlife Units. The following table summarizes training activities at the 45 units during 1974-75:

	Fishery		Wildlife	
	M.S.	Ph.D.	M.S.	Ph.D.
Students in Program ¹	273	69	234	55
Degrees Granted	50	9	71	8
Employment				
Fish and Wildlife Biology	52	9	54	9
Other Biology	6		3	3
Continue Education		13		11
Peace Corps				3
Misc. and Unemployed		3		10

¹Includes students who accepted employment before completing all degree requirements.

Cooperative Fishery Research Units

Auburn University, Auburn, Alabama.—Research during the year was centered on the development of methods for the control of fish reproduction. Auburn University's extensive pond facilities facilitate work on several aspects of reproduction, directed both toward improving the potential among some desirable species and subduing or eliminating spawning in species which tend to over-reproduce. One effort is aimed at producing channel catfish fry on demand rather than on the present seasonal basis; clomiphene citrate (a chemical used to increase human fertility) is being tested for induction of spawning in this commercially valuable species. In another series of experiments, one-sex progeny are being produced for controlled stocking of species in which further reproduction is undesirable. The grass carp, for example, might serve as a relatively safe biological weed-control agent if reproductive failure of stocked fish could be guaranteed. In another project, cultured tilapias (cheaply produced animal protein sources) were found to grow fastest when no competing young were produced by the stocked fish.

The feeding of androgens (especially 17 a-ethynyltestosterone) to young tilapia yielded fast growing, all-male fish. Another approach showing promise is the production of monosex progeny by mating functionally sex-reversed fish with normal fish of the same sexual genotype.

University of Arizona, Tucson.—The sport fishery of Parker Canyon Lake was studied, with emphasis on the biology and harvest of the stocked rainbow trout and their compatibility with stocked channel catfish and naturally reproducing largemouth bass, green sunfish, and bluegills. The first of five monthly stockings of 8- to 10-inch rainbow trout was on 6 November 1973. Newly released rainbow trout dispersed to the littoral areas around the lake. They fed primarily on zooplankton during December to February and on midge pupae or larvae during March to May. Growth was good and condition factors were similar to those of rainbow trout in the lake before the introduction of warmwater species. By the end of April, 90 to 95% of the rainbow trout had been caught by anglers.

The plant beds in the littoral zone provided the warmwater species with food, cover, and spawning sites. Crayfish were the primary food for most of the warmwater species. Although the food and habitat preferences of rainbow trout and the warmwater species overlapped, no adverse effects seemed to result. The sport fishery in Parker Canyon Lake is apparently biologically compatible.

Humboldt State University, Arcata, California.—Various aspects of the biology of adult summer steelheads were studied in the Mad River in California. The California Department of Fish and Game introduced this form in the stream because the adult fish may migrate upstream during months when fishing conditions in the river are optimum. Sampling by Unit personnel began in September 1973; 193 returning hatchery-reared steelheads and 34 native summer steelheads were examined. During spring 1974, 77 adults were trapped, tagged, and released to determine seasonal movements. In 1974, summer migration of steelheads up the Mad River peaked in early May and again in late October. Tag returns and underwater surveys showed that steelheads, which did not enter the hatchery in the spring, remained in or near tidewater during the summer, and then moved upstream after the first fall freshet. Upstream movement in the spring was positively correlated with both stream flow and turbidity; the upstream migration in the fall was positively correlated with turbidity and negatively with water temperature. Marked smolts planted in March and in April produced similar numbers and sizes of returning adults.

A study in Ruth Reservoir (an impoundment managed

by the California Department of Fish and Game) is providing biological information on the populations of stocked rainbow trout and golden shiners and on plankton. Fish and plankton were collected at four stations from June 1974 to May 1975. Zooplankton counts ranged from 0 to 175 organisms per liter. Golden shiners, brown bullheads, and suckers accounted for 90% of the gill net catch, and rainbow trout, white catfish, and largemouth bass made up the remainder.

Colorado State University, Fort Collins.—Although information about numbers of anglers using sport fisheries is a prerequisite to rational management, the data are extremely expensive to collect by conventional means. As a possibly less expensive alternative to the usual visual counts of anglers, automatic remote cameras were evaluated and found to be useful in some situations. Although individual anglers along typical lake shorelines could not be discerned on the film from 8-mm movie cameras, ice anglers could readily be counted. Boats and parked cars were also accurately recorded and provided a basis for estimating numbers of anglers present.

Pollution studies often result in such large masses of diverse environmental measurements that discerning their meaning becomes extremely time-consuming. Concern about this problem led to the development of several new statistical methods that should facilitate the assessment and evaluation of pollution in aquatic systems. The methods also show promise in other research where several variables must be simultaneously considered.

Changes in ground-water quality related to clear-cutting in western forests were investigated from the viewpoint of their relation to water quality in streams. Elevated levels of some important plant nutrients were observed on clearcut plots as long as 9 years after cutting. The most dramatic and ecologically important change was a ten fold increase in nitrate.

Because the complexity of fishery management decision making is beyond the integrative ability of an individual, a computerized model for the management of small trout lakes was developed. The model reflects the decision-making process that experienced fishery managers would probably follow if they had the time to use all existing information to plan the management of the lakes.

University of Georgia, Athens.—The discharge of thermal effluents into lakes and rivers from an increasing number of power plants has caused much concern among environmentalists. The Georgia Unit has used a series of cooling reservoirs at the Savannah River (South Carolina) Plant of the U.S. Energy Research and Development Administration to study the effects of heated effluents on certain aspects of fish life history. In one study in which ultrasonic tracking gear was used, adult bass moved freely throughout the reservoir when the water was not heated,



Live capture of small reef fishes for aquaria is a significant marine fishery in Hawaii, recreationally and commercially. Collectors commonly capture the 2-to 3-inch white-spotted toby for local hobbyists and for export to the mainland. A member of the sharpback puffer family, it is a slow swimmer and relies on inflation as one means of protection. (Hawaii Cooperative Fishery Unit photo)

but congregated in a few small refuge areas during periods when water temperatures neared 86°F. Maximum water temperatures from which bass were taken were 96° for adults and 102°F for immature fish. Bass occasionally died when subjected to rapidly rising temperatures. Spawning occurred between December and March when the water temperatures were coolest. Bass reached lengths of 11 inches in the first year of life, even though growth ceased during the hottest period of summer because of the stresses of overcrowding, reduced food supply, and high water temperatures.

University of Hawaii, Honolulu.—Unit research projects encompass both inshore marine and inland waters, emphasizing native species and their environmental requirements. The principal marine study concerns the saltwater aquarium fishery by hobbyists and commercial collectors and its effects on reef ecology. The first analysis of catch statistics was completed. Although three-fourths of the 248 "licensed" collectors were amateurs, most of the fishes were taken by commercial professionals. The catch in fiscal year 1974 had a gross value in excess of \$250,000. Population levels of the top 10 species taken commercially were estimated in various locations and habitat types; the effects of collecting on fish community structure is undergoing long-term assessment by the comparison of populations in pristine and in heavily

exploited areas. Ages of two species of butterfly fishes were evaluated on the basis of daily bone growth increments, determined by optical and scanning electron microscopy.

Biological studies on two native atyid shrimps were completed. One, the small red *Opaeula* used by Hawaiians as "chum" in ocean fishing, was found to have an unusual nonfeeding larva that completes development in only five stages. Stream habitat loss by dewatering is the major factor in the decline of native freshwater fauna, as shown by an environmental survey of West Maui drainages; only 2 of 17 originally perennial streams still flow continuously to the ocean and both are threatened by imminent diversions. The Unit collaborated with the University of Hawaii's Water Resources Research Center in inventorying Kawainui. This 1.3 square-mile Oahu marsh is Hawaii's largest freshwater wetland; it is a valuable waterbird habitat and is subject to developmental planning. Although most aquatic animals collected were exotic species, significant populations of native fishes and crustaceans were found at the seaward end of the marsh.

University of Idaho, Moscow.—In 1968, at the request of the Idaho Fish and Game Department, Unit personnel assessed the status of the seriously declining cutthroat trout stocks in the St. Joe River in an attempt to determine



Members of the jack family are popular sport catches in Hawaii and important top-level carnivores in the coral reef ecosystem. Large individuals, like this 3-foot ulua, are now seldom seen in waters around the inhabited islands of Hawaii but are common in the vast shallows surrounding islets on the Hawaiian Islands National Wildlife Refuge, where this picture was taken. (Hawaii Cooperative Fishery Unit photo)

what management alternatives might be available. Four major points were established: (1) the population of cutthroat trout in the St. Joe River was relatively small, (2) the fish were harvested soon after entering the river from the tributaries, (3) a large portion of the annual mortality was due to angling, and (4) the drainage was inadequately seeded because few fish survived long enough to mature and spawn. In short, the population was being overexploited.

In 1971, the Idaho Fish and Game Commission instituted special regulations on the upper half of the St. Joe River designed to save the cutthroat trout population. The bag limit was reduced to three fish and the minimum size limit was increased to 13 inches. No fishing with bait was allowed because most of the fish caught would be under-

size and would have to be released.

In 1974, after 4 years of the special regulations, biologists equipped with snorkels counted up to 5 times more cutthroat trout along established transects than they did in 1969-70. The annual mortality rate had decreased by about one-third and the size of fish had increased significantly. Fishing effort decreased during the first year of special regulations and then increased to a level equal to that before special regulations were imposed. The catch rate increased from less than one cutthroat trout per hour in 1968 to more than four in 1973. Although the special regulations have reversed the decline of this overexploited cutthroat trout population, full recovery is not expected until the late 1970's.

Iowa State University, Ames.—Efforts during the year

were concerned primarily with the Biological Services program of stream alteration, an evaluation of environmental contamination with dieldrin, and research on warmwater fishes. As part of a study of the effects of stream channelization and bank stabilization on warmwater sport fishes, aerial photographs of Iowa streams draining more than 50 square miles established that 84% of the total stream length in the Missouri drainage and 76% of that in the Mississippi drainage could be classified as nonmeandering, i.e., 1.5 miles or less of stream per mile of river valley.

The extensive stream channelization in Iowa, as well as natural bank erosion, has necessitated the installation of numerous bank-stabilization devices, some of which were retards and permeable jetties that increased maximum stream depth by 10-100%. Benthic samples collected adjacent to rock revetments and jetties contained significantly more caddisflies and mayflies—both important food items of game fish in the streams—than did samples from control areas. The structures used in Iowa could further improve the habitat of game fish if rocks of larger diameter were used as construction material, where possible, and if jetties were extended further into the stream.

The weight of drift organisms in study streams was significantly correlated ($P=0.95$) with stream sinuosity (channel length divided by downvalley distance), whereas the volume of organisms colonizing substrate samplers increased with current velocity. Fish species diversity was unrelated to stream sinuosity.

Louisiana State University, Baton Rouge.—Descriptive limnology of large rivers and swamps has been emphasized by the Louisiana Unit for the past 5 years. A 27-month survey of baseline conditions in a 10-mile reach of the lower Mississippi River was concluded during the year. Certain results that may be relevant to such Service-wide programs as stream alteration, power plant siting, and wetlands inventory are as follows: (1) The lower Mississippi is much more dynamic within a reach than the available literature indicates. Temporal changes in water quality and biota are difficult to predict. In the 10-mile reach under study, changes in water quality (i.e., dissolved oxygen, pH, inorganic nutrients) are seldom affected by biota except at low-water stages. (2) Although estimates of standing stocks of phytoplankton, zooplankton, benthos, and fishes are relatively low, the diversity of the communities testifies to the lower river's maturity and stability. (3) Extensive revetment of the river for levee protection is reducing habitat diversity, and increasing currents are reducing both the area of floodplain inundated and the duration of inundation. (4) Dwindling areas of floodplain in the lower river basin appear to be the primary nursery areas for indigenous fishes.

One research project of the Unit concerns the Atlantic

croaker, which has a life cycle typical of that of other important sport and commercial fishes in the Gulf of Mexico. Sampling in trawls and traps completed in 1974 in a marsh nursery area indicated that emigration of juvenile croakers from the nursery toward the gulf was complete by the end of June, and suggested that the primary stimulus initiating emigration before the end of April was a sudden drop in temperature (thereafter it appeared to be a sudden drop in salinity). Research on the use of this nursery area by croakers is continuing. A full understanding of the croaker life cycle would increase our ability to manage this species and others with similar life cycles.

University of Maine, Orono.—Surveys of the St. Croix River indicated that physical and chemical conditions in this stream may be temporary barriers to the return of adult Atlantic salmon from the ocean; for example, dissolved oxygen dropped below 20% saturation in the lower river in August 1974. Potential predators, primarily chain pickerel, are present but do not constitute a major obstacle to smolt migration. The sport fishery on the river was light (0.5 man-hour per mile per day) in June and early July and negligible in late July and August. The sport fish catch was composed of 40% smallmouth bass, 36% white perch, 13% chain pickerel, and 11% trout and salmon. Catch rate was 0.9 fish per man-hour.

A study in South Branch Lake revealed that chain pickerel grow slowly during the first year of life but rapidly during later years. Most fishing pressure was exerted on this species during the winter, when an estimated effort of 770 angler hours yielded an estimated catch of 235 pickerel. Male pickerel in the catch averaged 442 mm in length and females, 516 mm.

Analysis of the ecology of the Penobscot River estuary was intensified during summer 1974 to more adequately describe conditions faced by returning adult Atlantic salmon. Surface temperatures, monitored continuously at three sites, exceeded 20° C during most of July and August in the upper estuary but rarely exceeded 18° C at midestuary. Salinity, water temperature, and dissolved oxygen concentration were determined semimonthly at 1-m depth increments along four transects established in the estuary. Dissolved oxygen concentrations dropped below 50% saturation in the upper 3 m during most of August in midestuary, and were frequently below 75% saturation during July and August over the entire 20 miles of estuary studied.

University of Massachusetts, Amherst.—The alewife is used as bait by sport and commercial fishermen. Perhaps more important, it is a prominent item in the diet of offshore species such as striped bass, bluefish, cod, and haddock. A long-term study of the anadromous alewife population in Parker River, Mass., was initiated in 1971

with the objectives of compiling biological and physical data on alewife migration and the river system for use in formulating a mathematical model and computer simulation.

To determine which environmental factors influence the rate of movement of alewives and to gather population data on the spawning migration; we monitored alewife passage from the estuary into fresh water of the Parker River by visual 10-minute counts each hour at the first of a series of six fish ladders. This monitoring has shown that the fish migrate only during daylight and that a positive correlation exists between movement rates and changing water temperature. Tagging the alewives at the first fish ladder with highly visible spaghetti tags allows the investigator to estimate their movement rates through the system to the spawning ponds. Travel time up the river varies considerably. The average time required for the fish to swim the 10.7 km to the spawning ponds is 2 days, but some fish travel this distance in less than 24 hours.

On the basis of these data, a set of equations to represent the system has been developed. The current model simulates the important behavioral aspects of the migrating population. Comparisons of plots of simulated and real data determine the predictive value of the model.

University of Missouri, Columbia.—A primary mission of the Unit is the development of facts and concepts which have application to the effective management of warmwater fisheries. Considerable emphasis has been placed on studies of important predators—largemouth and smallmouth bass and members of the pike family.

The smallmouth bass has been shown to be adaptable to some Missouri ponds when it is stocked with minnows; when stocked in new lakes with largemouth bass and bluegills, however, the species has failed to establish successful populations.

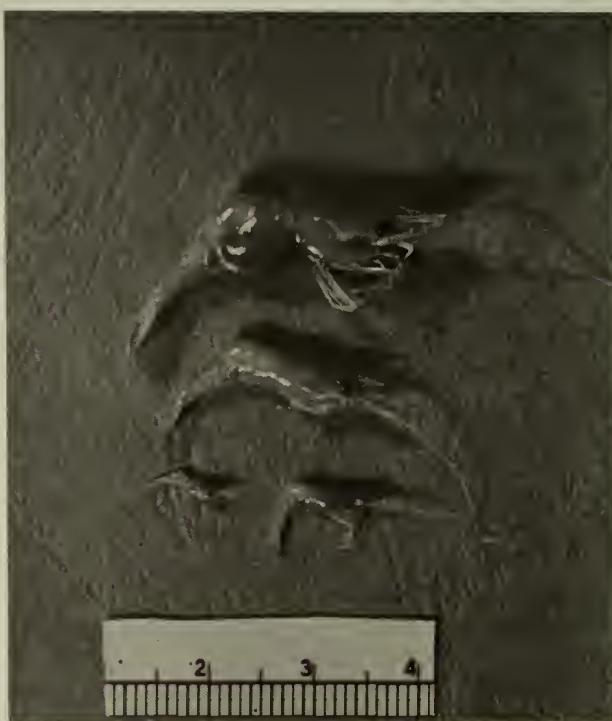
Members of the pike family are considered prime candidates for stocking because they grow rapidly and feed readily on gizzard shad, the most abundant prey species in most midcontinental reservoirs. In a comparative evaluation in ponds, growth and survival were better in the hybrid tiger muskie than in either parent species (northern pike and muskellunge).

Effective regulation of the largemouth bass harvest may be the most important management technique available for enhancing the quality of fishing in warmwater ponds, lakes, and reservoirs. Conservative regulations are required for many waters if the bass is to be an effective predator and if the quality of bass fishing is to be improved. The establishment of appropriate length limits appears to be the most effective regulation for improving or sustaining a satisfactory balance in bass populations in warmwater fish communities. Minimum length limits of 14-18 inches appear appropriate when reproductive suc-

cess and the annual rate of recruitment to catchable stock are relatively low. Maximum length limits or protected size ranges that allow harvest of a surplus of small adult bass may be appropriate when reproductive success and recruitment are relatively high.

Manipulation of the invertebrate links in a food chain is a relatively new approach toward enhancing the ecological efficiency and sport fish production of ponds and lakes. Introduction of the freshwater glass shrimp (*Palaemonetes kadiakensis*) to ponds appear to offer promise as a means of increasing the abundance of food for bluegills.

Montana State University, Boulder.—Closure of Yellowtail Dam on the Bighorn River in 1965 created prime trout habitat below the dam where only marginal trout habitat existed before. During 1972 and 1973, use and harvest was determined by creel census in the 14 miles of the river immediately below Yellowtail Dam. An estimated pressure of 18,648 fisherman days—among the highest fishing intensities in Montana—yielded 37,721 trout (90% rainbow trout) from 28 April through 9 September 1973. Growth rates of trout were excellent. In 5 months, trout grew 6 inches; the length of marked hatchery rainbow trout increased from 6 to 12 inches and that of wild brown trout increased from 7 to 13 inches. The



Freshwater shrimp (*Palaemonetes kadiakensis*): upper, gravid female; middle, mature male; lower, juveniles. The scale is 32 mm (1-1/4 inches) long. (Missouri Cooperative Fishery Unit photo)



Biologist using electrofishing gear to remove an adult largemouth bass from a pond immediately before the spawning season. If bass nearing spawning condition are held in tanks at 17-18° C (62-64° F) for later release into a pond, spawning can be delayed until as late as July. (Photo by D. M. Payne)

average total length of 4-year-old brown trout was 22.5 inches.

One of the seven known spawning populations of paddlefish in the United States supports an intense fishery at Intake, Mont. Because the popularity of this fishery had increased greatly since 1964, and there was concern that this prized resource might be overfished, a creel census was undertaken during 1973 and 1974 for comparison of the current status of the paddlefish with that in 1964. Fishing pressure increased about 10% from 1973 to 1974 (to about 11,155 hours in 1974). Some 22% of the fishermen in 1973 and 1974 were nonresidents, as compared with only 5% in 1964. The estimated yield of paddlefish was 45 metric tons in 1973 and 39 metric tons in 1974. The average weight of male paddlefish increased from about 10 kg in 1964 to 11 kg in 1974. The major age groups of males harvested ranged from VIII to XII in 1964 and from X to XIII in 1973-74. Females, which were extremely scarce in the 1964 total, made up 34% of the catch in 1973 and 38% in 1974. It was concluded that the

population of paddlefish at Intake was not being overfished at current yields.

Cornell University, Ithaca, New York.—A long-term project on the reproduction and early life history of largemouth bass is directed toward learning what causes the heavy mortality that normally occurs during the first few weeks after egg fertilization. In the past, field observations have been limited largely to the approximately 5-week spring spawning period. During the past year, however, a Unit biologist discovered that the largemouth bass spawning period could be greatly extended by removing brood bass from ponds shortly before the onset of spawning in mid-May, when water temperatures were 17-18° C (62-64° F), and holding them in tanks at those temperatures for 1 month, under moderately crowded conditions. When the bass were then stocked in ponds at water temperatures near 24° C (75° F), spawning occurred almost immediately. Using this approach, the investigator was able to extend largemouth bass reproduction into early July, and maintain a 75% hatch of the eggs spawned.

In a cooperative project with the Tunison Laboratory of Fish Nutrition, the feasibility of incorporating the wastes of the egg products industry into fish feed as a replacement for fish meal has been demonstrated. Nearly 10% of the 7 billion eggs processed annually by the egg products industry in the United States are wasted to sewers, thus creating a considerable water treatment and pollution problem. Although the essential amino acid profile of whole chicken egg protein has been used as a standard in formulating fish feeds, eggs have not been used in fish feeds because of economic constraints.

When dried egg processing wastes were used to replace 50% of the fish meal in experimental feed fed to fingerling lake trout, growth and survival of the fish were slightly better than the growth and survival of fish receiving a standard practical diet in which fish meal was the primary protein source. Cost of producing the dried egg waste product was about 10 cents per pound—a price that compares favorably with the current price of fish meal. If subsequent tests demonstrate the acceptability of egg wastes in diets for other species and at other replacement rates, the wastes of the egg products industry may be converted from a water treatment and pollution problem to a valuable source of protein for the fish culture industry.

North Carolina State University, Raleigh.—The three primary subjects of research in 1975 concerned stream ecology, power plant siting, and the genetics of warm-water fish. The stream ecology work consisted of intensive studies of the aquatic fauna of unaltered and altered wooded swamp streams of northeastern North Carolina. Information about the physical and chemical characteristics of these streams is being related to movements, spawning, and other life history aspects of fishes. Estimates of fish populations were conducted, as were major studies of environmental variables and their relations to aquatic forms.

A major thermal electric plant that became operational in 1975 obtains its cooling waters from the Lower Cape Fear River. Inasmuch as the fishes and their habits in this estuarine area are little known, Unit personnel are conducting studies to determine the abundance, movements (by ultrasonic tracking and conventional tagging), and impingement rates of various species.

Basic genetic information is lacking on the heritability of growth factors and on the characteristic numbers and types of chromosomes in many species of fish. Methodologies for obtaining such information are being developed, and data are being collected for various species of catfish and sunfish.

Ohio State University, Columbus.—Food, age, and growth of white crappies were studied in an upground reservoir, a type of reservoir created when an embankment is constructed around a section of flat land and water

is pumped into the enclosure from a nearby stream. The reservoirs, commonly used for water storage in areas of flat topography, offer a unique fish management opportunity. White crappies from a typical Ohio upground reservoir fed primarily on zooplankton and midge larvae throughout their lives. The lack of forage fish adversely affected the growth of adult crappies, which usually feed primarily on fish. The management program indicated involves increasing cover and shallow water habitat in the reservoir and stocking it with forage fish.

The anoxic hypolimnetic water of a 0.73-ha quarry (maximum depth, 18 m) was oxygenated by the introduction of compressed liquid oxygen. Oxygen levels were maintained at 8.0 mg/l in 1973 and 21.5 mg/l in 1974, without destratification. Zooplankton became abundant in the hypolimnion, and anaerobic benthic forms were replaced by aerobic forms. Survival of stocked trout was excellent, and a two-story fishery was maintained throughout the summers of 1973 and 1974.

Oklahoma State University, Stillwater.—Oklahoma now has a total water area of 300,275 ha (741,993 acres), including 76,720 ha (189,579 acres in farm ponds of less than 10 acres, 1,777 lakes 10 acres or larger with a total area of 44,989 ha (111,170 acres), and 24 major reservoirs with a surface area of 178,566 ha (441,244 acres). Lakes Texoma, Eufaula, and Grand contribute 96,316 ha (238,000 acres) of the total water area. Oklahoma leads the nation in the construction of upstream flood-prevention dams under Public Law 566. Fishery management in these many and diverse man-made lakes has evolved without adequate knowledge of the nature of the environments and their special problems, but certain generalizations have been developed regarding their ecology and productivity. At the Oklahoma Unit attention has been focused on a number of projects directly concerned with fishery management in these man-made lakes: (1) characteristics of reservoir sediment and its distribution and behavior; (2) food of important game and commercial fishes; (3) population dynamics of game and commercial fishes; (4) effects of reservoir destratification; (5) movements of flathead catfish and striped bass (as monitored with ultrasonic tracking equipment); and (6) the relation of water level to the year-class strength and growth of fish. This research, all of which directly or indirectly concerns the factors controlling productivity in impounded waters, should yield tenable management strategies where only intuition and trial-by-error have been available in the past. On the basis of their research and that of many field biologists, Unit personnel are making a major effort to develop a practical model for predicting maximum-likelihood strategies for optimum management of largemouth bass populations in individual impoundments.



Samples of various tissues are collected from rainbow trout for genetic studies. (Oregon Cooperative Fishery Unit photo)

Oregon State University, Corvallis.—Unit personnel are involved in physiological and genetic studies of anadromous fishes and the ecology of inland trouts. During the past year, among coho salmon returning to Big Creek Salmon Hatchery near Astoria, Ore., the number of precocious males ("jacks") was shown to be largely under the influence of additive genetic factors. This finding indicates that the number of jacks can be manipulated by brood-stock selection procedures. In selective breeding experiments, the yield (number of adults returning divided by number of juveniles released) of 1971-brood Big Creek coho salmon was increased by 8.2%.

In other studies, gene frequencies at several loci in steelhead trout and chinook salmon were found to be variable in Oregon stocks. Obvious differences were found between Columbia River stocks and Oregon coastal stocks, and genetic differences between spring and fall races of chinook salmon were defined.

Pennsylvania State University, University Park.—In studies of competition between wild and hatchery-reared brown trout, agonistic (combative) behavior appeared to be higher among hatchery trout. For either wild or hatchery trout, prior residence in a stream section was more important than size as an advantage in agonistic behavior. Among hatchery and wild brown trout of equal size, hatchery trout were dominant over the wild. The male was usually dominant over the female, except during spawning. When first introduced into new waters, wild fish

schooled. Wild brown trout moved less than hatchery fish, used cover more extensively, spent more time resting on the bottom, and fed less than hatchery fish—although they grew more rapidly.

Of the inbred and hybrid brook trout strains tested, 75% exhibited inter-strain differences in activity and in use of cover.

Mature smallmouth bass did not distribute themselves with reference to the randomized distribution of cover. Agonistic and behavioral interactions were centered at certain obvious locations. Some areas, apparently without unique distinction from others, were rarely used. Dominant smallmouth bass had no statistical advantage in growth over subordinates.

South Dakota State University, Brookings.—Studies are being conducted on the rearing of small fish in potholes and marshes of the South Dakota Glacial Lake District to a size suitable for stocking in other waters. These abundant shallow, eutrophic waters in the glaciated portion of the northern Midwest are highly productive, but support no natural fish populations because they are subject to winterkill. However, the habitats do provide areas where young fish can be stocked and left until they reach a desirable size for restocking into larger bodies of water. Such a program provides a means of using the high productivity of wetlands to produce a desirable-sized sport fish for stocking, at a relatively low cost. In one study, a 30-acre pothole was stocked with 25,000 walleye fingerlings in June and the growth rate and feeding of the fish were monitored until October. The efficiency of three capture methods was evaluated when the walleyes were removed from the pond.

The average total length and weight of walleyes in the pond increased from 43.5 mm and 0.5 g on 13 June to 167.1 mm and 41.2 g on 13 September—a gain of 123.6 mm and 40.7 g. Stomachs of 177 walleyes examined during the period contained three major types of food—zooplankton (*Diaptomus* sp.), fathead minnows, and aquatic insects. *Diaptomus* sp. was in 49.7% of the stomachs and made up 8.0% of the total food volume; fathead minnows were in 26.6% of the stomachs and contributed 69.2% of the volume; and aquatic insects were in 21.5% of the stomachs and made up 17.6% of the volume. Walleyes fed primarily on *Diaptomus* until mid-July, when they began feeding primarily on fathead minnows. Fathead minnow populations declined by mid-August, and the walleyes were forced to seek an alternate food source. Aquatic insects (mostly midge larvae) became the primary food. A total of 4,416 walleyes (17.7% of the number stocked) were removed from the pond and stocked in lakes. The numbers of walleyes removed per man-hour by the three methods of fish removal tested were: electrofishing, 75.2; seining, 45.0; and trapnetting,



Artificial cover (slabs) installed in a seminatural stream to study the cover-seeking behavior of competing wild and hatchery brown trout.
(Pennsylvania Cooperative Fishery Unit photo)

10.1. Studies are continuing in similar waters on methods of culture and removal of walleyes, northern pike, and paddlefish.

Tennessee Technological University, Cookeville.—A study of the population dynamics of largemouth, small-mouth, and spotted bass in Center Hill Reservoir, from April 1974 through June 1975, included the determination of age-growth relation, fecundity, food habits, natural mortality, and fishing mortality. Data from this study are being synthesized for incorporation into a computer simulation model to predict the consequences of various management strategies.

The population dynamics of walleyes in Center Hill

Reservoir were also investigated during the year. The primary objective was to collect data on age and growth, fecundity, and food. Walleye populations in this reservoir grow more rapidly than other populations for which growth data have been published. The primary food of walleyes in the reservoir was threadfin shad.

The relative attractiveness of single and multiple groupings of stake beds to fish was evaluated in Cordell Hull and Center Hill Reservoirs by applying rotenone to coves, fishing with submerged trotlines, and angling. Total weight and number of crappies and other game fish collected in coves with stake beds were compared with those in control coves (i.e., cover without stake beds). Catches

of crappies on submerged trotlines and by angling were the basis for comparison of their availability over stake beds, in control areas, and in natural cover areas in the reservoirs. Although stake beds concentrated crappies and other game fish, sport angling was far more successful in natural cover areas.

Utah State University, Logan.—Utah and other states of the intermountain West contain substantial amounts of valuable natural resources that are becoming progressively more important to our country. Water is an important commodity in this region, and increasing demands for various uses such as agriculture, industry, mineral extraction, and recreation are often conflicting. Therefore, the Unit is attempting to determine the impacts of man's alterations on the aquatic environments and to provide alternatives that will minimize these impacts on fish and wildlife. During the academic year 1974-75, 15 graduate students were conducting research on various phases of this problem.

A recently completed project of the Unit concerned the respiratory metabolism and energy requirements of embryonic, larval, and juvenile mountain whitefish. This species is a key form in many streams in the western states and can serve as an indicator species, but little is known about its life history. The embryonic development was similar to that of other whitefishes. The upper optimum temperature for successful development was 6° C; at temperatures of 9° C and higher, the development process was greatly disrupted and the mortality of eggs and abnormalities of hatched larvae were greatly increased. The optimum temperatures for growth of the post-yolk-sac larvae were 9° and 12° C. Among underyearlings, active metabolism was highest at 9° C and decreased significantly at 15° C; standard metabolism increased gradually between 6° and 12° C and then rose sharply at 15° C; and scope for activity was highest at 9° and 12° C and lowest at 15° C.

Virginia Polytechnic Institute and State University, Blacksburg.—Recent increases in energy demands and concomitant increases in thermal discharges of cooling water have emphasized the problem of thermal impacts on aquatic ecology. The impact of sublethal stresses is poorly understood. Fathead minnows were acclimated at 18° C, then exposed to 32° C for 85 minutes twice daily for 1 week. Under the test conditions, stressed fish were no more susceptible to predation by largemouth bass than were control fish. Inasmuch as research by other investigators has indicated that thermal stress increased the susceptibility of juvenile salmon to predation, the absence of a similar result with fathead minnows may indicate that temperature-tolerant species (such as fathead minnows) recover more quickly than temperature-intolerant species (such as salmonids) from sublethal thermal stress.

In spite of the wide use of electroshocking in fish management to sample populations, the effects of its use on fish is not well understood. These effects were examined by subjecting fantail darters and bluegills to levels



The paddlefish is among the species being reared experimentally in small shallow ponds of the northern Midwest for later restocking in larger waters. Here eggs (top) and milt (bottom) are being collected as the first stage in the production of fry for use in the stocking-restocking program. (South Dakota Cooperative Fishery Unit photo)

and patterns of electricity within the ranges employed under field situations. Mortality of fish exposed to pulsating direct current increased with increased pulse frequency, voltage gradient, and exposure time. Mortality increased with fish length when fish were subjected to increased exposure time and total voltage, but not to increased pulse frequency. Fish sustained little mortality when exposed to pulsed direct current with pulse frequencies of 30 pulses per second or less and voltage gradient levels of 14.0 volts per centimeter or less. Fish exposed for 15 seconds or less sustained negligible mortalities, regardless of the electrical characteristics of the gear. Electrostroshock of rainbow trout resulted in a delayed but significant increase in plasma glucose concentrations but did not significantly affect plasma protein, calcium, magnesium, or androgen levels. Corticoid and glucose levels, however, remained high for at least 6 hours. Apparently a substantial period of time is required for fish to return to "normal" after being stressed by electroshock.

University of Washington, Seattle.—The life history and ecology of freshwater, estuarine, and marine fishes are being investigated. Work on freshwater forms was concentrated on certain dominant fish species of Lake Washington, an 8,950-ha lake adjacent to the campus of the University of Washington. Studies on the life history of the northern squawfish and black bullhead were completed in 1975; studies on yellow perch and prickly sculpin are under way. A computer model is being developed that will describe energy budgets and competitive relations of the various species.

The effects of log rafting on estuarine fish and invertebrates are being investigated in Everett Harbor, Wash. Log rafts in the area are grounded on the mudflats at low tide. The resulting substrate disturbance may be deleterious to benthic invertebrates, many of which are important in the diets of marine and anadromous fishes. We are determining the distribution and abundance of fish in log-rafting areas, and monitoring recolonization by benthic invertebrates after log rafts are removed.

Fish diseases and parasites are another area of major interest. One current project is concerned with parasitization of salmonids by eye flukes, a serious problem in some Washington lakes. An attempt is being made to immunize salmonids against the fluke. The relative susceptibility of several salmonid species to fluke infection is also under study; it may be feasible to control the problem by planting only the more resistant species in fluke-infested lakes.

University of Wisconsin, Stevens Point.—Among the more than 15 field or laboratory studies under way during the year, one of the most important concerned the movements and population dynamics of the walleye in the Red Cedar River and Lake Menomin, Wis. A single population occupied downstream Lake Menomin and the inflow-

ing river upstream as far as the first dam. Catches, both by anglers and by biologists using experimental electric fishing gear, were high in the river in spring and fall and low in summer—indicating that walleyes concentrated in the river during the spring spawning season, migrated downstream into the lake in summer, and then upstream again in fall. In this 2-year study more than 700 walleyes 250 mm (10 inches) long or longer were tagged. The average annual angler exploitation rate for these fish was 31% (three estimates in different parts of the river in different years were 31, 32, and 30%). The annual total mortality (fishing plus natural) was 50% (the separate estimates were 51, 49, and 50%). Calculation of equilibrium yield per unit recruitment indicated that the weight of walleyes harvested could be increased by 27-38% with minimum length regulations of 328 and 419 mm (13 and 16.5 inches), in the absence of substantial mortality of released undersized fish.

Cooperative Wildlife Research Units

Auburn, University, Auburn, Ala.—A telemetric study of reproduction, habitat use, and the effects of human disturbance on wild turkeys was conducted from 1972 to 1974 at Land Between the Lakes National Recreation Area in western Kentucky. The population density of turkeys was about 1 per 225 acres. Tags were placed on the patagia (wing membranes) of 103 turkeys and 55 were also instrumented with radio transmitters.

The estimated percentage of hens that successfully raised one or more pouls was 67 in 1972, when it rained only 1 day during the hatching season, and 35 in 1973 and 31 in 1974, when it rained for 16 and 12 days, respectively. The average number of pouls per successful hen in 1972 was 43% higher than in 1973 and 78% higher than in 1974. Hatching dates of 33 pouls captured in 1972 indicated that the peak of hatching occurred during the first part of June. Subadult hens were not observed to nest nor were any seen with pouls.

Nest predation was high during this study; the nests of all 11 transmitter-equipped adult hens were destroyed. After 14 days, 55% of 80 dummy nests were destroyed by predators. The only nest known to have been deserted because of human activity resulted from mowing. Hens whose nests were destroyed were not observed to renest, and no "late" pouls were seen that would suggest renesting.

Five hens and five gobblers had average minimum summer ranges of 651 and 441 acres, respectively. Maximum movements were fairly consistent for birds of both sexes, averaging 1.5 miles. Some radio-tagged birds made brief excursions to areas as far as 2 miles from their summer ranges. Two instrumented gobblers moved 3.8



Alert turkey gobblers in Alabama. A study of the effects of human disturbance on wild turkeys indicated that the birds avoided the area of a newly opened foot trail. (Photo by D. W. Speake)

miles from summer to winter ranges, and five gobblers, in three flocks, moved from an area intensively hunted by archers to a "no hunting" area 2 miles away.

Instrumented turkeys exhibited no apparent preference for timber stand classes within their summer ranges. Vegetative composition of ranges varied greatly. Sawtimber varied from 25 to 90% and pole timber from 10 to 75% of the turkey ranges. Turkeys readily used selective timber harvest areas within their summer ranges, and they were frequently observed in clover, winter wheat, and mowed fields during spring and summer.

Turkeys did not regularly use a 2,500-acre area set aside for off-road vehicles. The traffic on a newly opened foot trail had an adverse effect on use of the trail area by turkeys. However, turkeys were known to range as close as 0.6 mile to a campground that accommodated an aver-

age of 12,000 visitors per month in the summer.

University of Alaska, Fairbanks.—The Steese-Fortymile caribou herd of interior Alaska has decreased markedly in size during recent years. Concurrently, the herd has undergone major changes in its pattern of movements. A field study was carried out in the Tanana Hills, beginning in summer 1973, to determine the role of various environmental factors influencing summer movements and behavior of the herd. Wind and temperature were found to influence the herd indirectly because of their effects on flying insects. Harassment by nasal bot-flies and warble flies may be an important factor in causing August dispersal of the herd. Wolves are the only important predators of the caribou, and apparently cause significant mortality, especially on calves. Caribou social behavior, especially that relating to the cow-calf bond, is

also important in controlling movements.

An investigation of the Dall sheep population in the Atigun Canyon area of the Brooks Range was undertaken during 1970-74 because of the proximity of the population to a construction camp and a proposed pump station on the Trans-Alaska pipeline. The population of sheep decreased from over 300 in 1970 to about 275 in 1974. Productivity fluctuated from 10 to 59 lambs per 100 ewes and lamb survival was high. Adult mortality increased rapidly after 8 years of age. Summer movements across the river valley began in June and extended for 25 miles. During these movements the sheep made frequent use of mineral licks. Winter ranges were reoccupied in August and September. The area of the winter range was a small fraction of that of

the total range used in summer. Management recommendations were suggested to minimize disturbance to sheep at critical times.

University of Arizona, Tucson.—The Mexican duck, an endangered species, used agricultural ponds as breeding, resting, and feeding places in Sulphur Springs Valley, Ariz. The agricultural pattern of the Valley is changing because ponds used as "pumpbacks" for irrigation are being replaced by overhead pipe sprinklers. One artificial pond area has been built and maintained by the Arizona Game and Fish Department in the Valley. Detailed information gathered there has shown that 17 species of ducks are present in the Valley at various times of the year. During winter the area also attracts hundreds of sandhill cranes and other water birds. About 150 Mexican ducks are resident in the Valley, perhaps making this region the species' major stronghold in the United States. The observed breeding population on the study area in 1974 consisted of 70% Mexican ducks, 25% mallards, and 5% recognized hybrids. One pair of pintails also nested. An annual average of 30 Mexican duck broods was known to have been produced from 1972 through 1974.

Studies of Mexican duck habitat showed that disturbance was the major factor influencing pond use by adults in summer. Ponds featuring low disturbance and dense cover were preferred by hens with broods. There were some indications that larger acreages attracted more waterfowl, but pond depth exerted no discernible influence. Waterfowl requirements changed in winter, but disturbance remained important in affecting the presence of Mexican ducks. Vegetation density became relatively inconsequential, and pond depth and acreage attained more influence; shallow water and large areas attracted more birds in winter than in summer.

Construction of irrigation ponds in the Valley has produced local sympatry (occupation of the same geographic range) of Mexican and mallard ducks. Resultant hybridization between the closely related forms may endanger the Mexican duck as a taxonomically distinct species.

Colorado State University, Fort Collins.—The winter habits of sage grouse were studied for 2 years in North Park, Colo., to gain information about segregation of the birds by sex, distribution in relation to available sagebrush, and differences between sexes in habitats occupied. Flocks were found to be the dominant social unit. Among 5,080 sightings, only 17 single grouse were observed. Strong flock segregation by sexes was evident; 81% of the 176 sample flocks were unisexual. Segregation was more pronounced in predominantly male than in predominantly female flocks, although females had a stronger tendency than males to form large flocks. Flock size was 50 or fewer individuals in 88% of all observations. Mean size of flocks was approximately 17 for males



The Alaska Cooperative Wildlife Research unit has studied the population and movements of Dall mountain sheep (top) in the Brooks Range (bottom) adjacent to the route of the Trans-Alaska Pipeline. As a result, the pipeline has been rerouted to avoid a major winter concentration and lambing area. (Photos by S. Linderman, top; D. R. Klein, bottom)



A Mexican blackduck. Studies of this endangered species in Arizona indicated that human disturbance was an important factor in their use of ponds in Sulphur Springs Valley. (Photo by L. C. Goldman)

and 39 for females.

Winter range was restricted because suitable sagebrush was lacking, snow cover was too deep, and many slopes were too steep. Only 50% of the sagebrush dominated lands in the study area were used during winter by the grouse. In general, female flocks used denser stands of sagebrush than male flocks did. Roosting, feeding, and loafing sites were similar in vegetative characteristics. Much of this wintering area is underlain by low-sulfur coal deposits and may be subject to extensive disturbance should strip mining operations develop. Because of the slow regeneration of disturbed sites, suitable sagebrush should be conserved in these areas. Only 4 of 199 flocks were observed in areas that showed evidence of alteration by 2,4-D spraying, plowing and seeding, or burning.

University of Idaho, Moscow.—The social organization of a mountain lion population in the Idaho Primitive Area was investigated using radiotelemetry. After dependence on their female parents ended, young lions dispersed without showing attachment to any particular area. As transients, young females did not reproduce and young males bred only rarely. In establishing home ranges, young lions restricted themselves to areas adequate in size and resources for their sustenance and free of other residents. Lions entered the reproductive phase of their lives only with an attachment to a site. Use of the home area by resident lions was influenced by the localizing effect of ungulate kills and, for females, by kitten mobility. A

lion's home area was in a constant state of flux, depending on location of its ungulate prey.

The mountain lion's essentially solitary existence was maintained visually and chemically. Resident lions occupied fairly distinct, but usually contiguous, winter-spring and summer-fall home areas. No substantial part of any resident lion's winter home area was maintained to the exclusion of all other lions. Resident male home areas overlapped but little, whereas home areas of resident females often overlapped completely with those of other females and with those of resident males. Transient lions of both sexes moved about these areas but did not remain. In summer, the home area pattern was the same.

Land tenure was based on prior right, but the system was not static because home areas were altered in response to death or movement of residents; young adults established home ranges only as vacancies became available. During seven winters from 1965 to 1972, the resident males of the population remained stable in numbers, but three females that died after the first three winters were not replaced. Dispersal of young lions reared on the study area was independent of the density of the resident adults. It was concluded that the land-tenure system maintained the density of breeding adults below a level set by the food supply. The area of terrain used by a resident mountain lion was determined by the density and vulnerability of prey in relation to vegetation and topography.

Iowa State University, Ames.—Recent declines in numbers of ring-necked pheasants in north-central Iowa are related to changes in land use and a marked decrease in prime nesting habitat, according to two separate studies. In one study, land use changes and their effects on pheasant habitat from 1938 to 1973 were analyzed in each of 27 counties in north-central Iowa, using sequential aerial photography and annual crop reports. During this period, there was a major shift in agricultural crops from small grains, hay, and pasture to corn and soybeans. Areas in wetlands, undisturbed grasslands, fencerows, and farm groves declined significantly. Total pheasant nesting habitat declined 44%, while nesting cover from which high production was expected declined 76%—from 30% of the land area in 1939 to 7% in 1972. Winter cover also declined from 2.6% to 1.8% of the land area during this period.

In another study, attention was focused on an area in Winnebago County where pheasant research has been conducted by Unit personnel since 1935. Spring population estimates made on this area in 6 different years between 1939 and 1954 ranged from 71 to 296 birds. Numbers dipped to 37 in 1967 and 12 in 1973. Previous estimates of fall populations ranged from 208 to 950 birds; in 1967 and 1973, the estimates were 67 and 28. Pheasant nesting success traditionally has been highest in small

grain fields and hayfields in the study area. In recent years, there has been a shift away from small grain and hay crops to corn and soybeans. An increase in fall plowing, which reduces winter cover and the amount of waste grain on which pheasants can feed, has accompanied the shift in crops. Pheasant cover along fencerows has also decreased. These factors have apparently prevented the pheasant population from recovering after severe winter losses in March 1965.

Louisiana State University, Baton Rouge.—One common marsh management technique used in tidal areas is the construction of weirs (drainage restraints) in channel outlets. Weirs preserve access to the marsh for sportsmen and trappers and often encourage desired aquatic vegetation by reducing fluctuations in water levels. Research was conducted in the marshes of Jefferson and Plaquemine Parishes in southeastern Louisiana during 1974 to investigate the effect of weirs on soil and water characteristics and on wildlife. Weirs did not appear to influence water turbidity, dissolved oxygen, or dissolved hydrogen sulfide in the free soil water. The data indicated that weirs have a buffering effect on changes in the salinity of the water and the free soil water, both of which were slightly higher behind weirs than in areas without weirs. Soil pH and oxidation-reduction potential were slightly lower behind weirs, and this was probably caused by the more stable water levels. Because weirs have the potential to alter marsh ecology, they probably affect wildlife populations, but this has not been adequately investigated heretofore. During low water, more ducks, coots, and nongame birds used wetlands influenced by weirs than adjacent control wetlands. Weirs had no measurable effect on numbers of fur bearers or small mammals.

The loss of pecans to animals, principally crows, in Louisiana has been estimated at \$2-6 million. These losses have been reported to be as high as 50% of the annual crop in recent years. Studies were carried out in northwestern Louisiana to ascertain the extent and cause of the damage. During the 1973 harvest season, pecan damage amounted to 6.26% of the total production of the sampled trees, 5.79% being attributed to crows, 0.43% to blue jays, and 0.04% to squirrels. Pecans made up 60.7 and 21.3% of the stomach contents of crows and blue jays, respectively, collected in or near pecan orchards. Of 36 species of birds identified in the orchards, 7 were considered to be potentially harmful to pecans. Numbers of crows, the most harmful species, increased in the orchards throughout the pecan ripening and harvesting season.

University of Maine, Orono.—The food habits of Maine coyotes were studied in the remote St. John-Allagash Wilderness of western Aroostook County, and compared to other data obtained State-wide. The diet of Maine coyotes appears to vary with availability and abundance

of food at different seasons and in different regions. In settled areas, coyotes eat a great variety of items including refuse, fruit, unretrieved hunter-killed deer, and domestic stock remains. In remote unsettled areas, coyotes appear to scavenge less and become more predatory, depending more often on white-tailed deer, snowshoe hares, and other wild animals. Food habits were determined by snow tracking, examination of scats, and stomach content analyses.

Nine snowmobile trails were established in the winter of 1972-73, to relocate groups of deer within a wintering area in western Maine. Various inducements were used to initiate trail-use response; the combination of chain saw noise and cedar foliage placed along the trail gave the best results. Relocation occurred in well defined stages and persisted as long as the new food supply lasted. During the winter of 1974-75, 10 snowmobile trails totaling 7.3 km were maintained between the center of large openings and adjacent sheltered bedding areas. Deer used these trails extensively to feed on forage otherwise inaccessible to them during winter. Of 257 deer encountered while snowmobiling during three winters, 107 (41.6%) stayed within sight as the machine passed, but only 15 (11.6%) of 129 deer remained when they were encountered by a person on foot. The deer were less inclined to run away in late winter, when snow exceeded a depth of 76.5 cm, when their sinking depth in open habitat exceeded 20.4 cm, and when they were in dense conifer cover.

University of Massachusetts, Amherst.—Although the northern red-shouldered hawk is probably the most common woodland hawk in New England, its numbers have declined in the last 20 years. A 2-year investigation was carried out on seven nesting pairs in the Quabbin Reservation of central Massachusetts to add information to the data base for this aesthetic and economically valuable woodland raptor. Courtship was observed throughout March, egg-laying during mid-April, hatching through late May, and fledging during the last few days of June and first few days of July. All nests were located on east or northeast slopes in wet deciduous woods, usually in black birch trees. These nests were lined with fresh hemlock or white pine sprigs. Home range size, averaging 90 ha, appeared to depend on the extent of wetlands adjacent to the nesting tract. The eastern chipmunk was the most common prey fed to nestlings. Parent and chick feeding behavior and other nesting behavior at four nests were recorded by automatic photorecorders installed in adjacent trees. The hawks reacted to repeated human disturbance during incubation by abandoning clutches at four nests. The population decline of red-shouldered hawks in the Northeast appears to be linked with habitat specificity and a sensitivity to human disturbance during the nesting period.



Adult and young red-shouldered hawks. From a study in Massachusetts, the decline of this species in New England appears to be linked with reduction of habitat and sensitivity to human disturbance during nesting. (Photo enlarged from 8 mm frame, Massachusetts Cooperative Wildlife Unit)

University of Missouri, Columbia.—A priority system for decision making in endangered species work was devised through a Missouri Wildlife Unit project, in cooperation with the Oregon Wildlife Unit. Priorities for action on endangered species are based on determinations of the imminence of the threat to the species and an appraisal of the potential for corrective action. Size and trend of existing populations, status of habitats, recovery potential based on reproductive capabilities and habitat manageability, and taxonomic uniqueness of the species are major factors utilized in a ranking system to quantify the endangered status of an animal. The numerical score from the system offers a chance to regularly assess priorities for research or management actions through systematically considering the plight of a large array of animals. A test of the system with 180 species, an assessment of the general data base on endangered animals, and peer review of the system and the philosophy behind it showed that it can be useful in ranking endangered status before making decisions for action. With growing lists of threatened or endangered animals constantly being affected by human activities, a standard information source is suggested for providing consistency in dealing with the huge volume of data necessary to set priorities for action.

Missouri Unit studies have shown that less than 100,000 acres of potential swamp rabbit habitat remain of the original 2.4 million acres in southeast Missouri. Less than half of the existing suitable habitat is occupied by swamp rabbits; much of the rest is in isolated tracts. Swamp rabbits require large acreages of habitat to maintain breeding populations, and the combination of high

land prices and scarce habitat makes preservation of large acreages difficult. Vegetative data and trapping results indicated that a thin canopy provides greater production of food or cover near the ground, thus increasing swamp rabbit carrying capacity. Proper size and spacing of canopy openings would be important in management because of possible competition with cottontails if openings were too large and too frequent.

University of Montana, Missoula.—Mortality suffered by domestic sheep was documented on the Eight Mile Ranch at Florence, Mont., from 15 March 1974 to 14 March 1975. During the first 7 months, predators were not controlled; thereafter control could not be withheld and ranchers, hunters, and trappers were allowed to take coyotes. A total of 644 sheep mortalities were recorded; 117 (18.2%) were lambs which died in the lambing sheds prior to exposure to predation. Field deaths numbered 527 (397 lambs and 130 adult ewes); 449 (85.2%) were attributed to predation, 66 (12.5%) were natural deaths, and 12 (2.3%) were undetermined. Coyotes, dogs, foxes, eagles, and ravens killed sheep during the study, but coyotes were responsible for 97.1% of the kills. Most of the sheep were killed just before dawn near bedding grounds; 71.8% of the carcasses had simple neck-throat wounds. Coyotes killed more sheep than they fed on, and they seldom returned to carcasses. The health of lambs killed by predators was similar to that of lambs shot for comparison. The average age of lambs killed was slightly less than the average age of lambs in the flock. Significantly more female lambs were killed than male.

The mountain sheep population near Thompson Falls, Mont., consisted of two herd segments which coincided with the original transplanted groups. Intersegment association was restricted to rams, but, within segments, group cohesion was low and interchange of individuals between groups was common. Mobility of the sheep was less in summer than in winter, but during both seasons it was greater than reported by other investigators. Overwinter mortality was low because of abundant available browse, mild weather, and lack of competition from other ungulates. Major foods were grass during fall, grass and forbs during winter, and browse during spring and early summer.

Cornell University, Ithaca, N.Y.—An ecological study of the wood duck was completed in the green timber research impoundment at the Montezuma National Wildlife Refuge. Spring flooded green timber produced ideal breeding habitat for wood ducks by providing ample acceptable nest cavities (1.6 per acre) and an abundance of early spring invertebrate foods, including fairy shrimp, cladocerans, mosquito larvae, isopods, amphipods, and gastropods. Use of nest boxes, evenly spaced (1.0 per 10 acres) beneath the forest canopy, augmented the breeding



Flooded green timber impoundment at Montezuma National Wildlife Refuge, N. Y. A dense growth of duckweed covers the water in the foreground. Biologists of the New York Cooperative Wildlife Research Unit completed an ecological study of the wood duck in this habitat. (Photo by D. Q. Thompson)

population of wood ducks (that depended on natural nesting holes) with a minimum of interference from starlings and common flickers. Wood duck nesting increased significantly from 22 nest starts in 1973 to 44 in 1974. Were it not for nest losses induced by human disturbance, successful hatches would probably have approached the 90% mark each season. Total seasonal production of day-old ducklings, estimated from recapture of web-tagged juveniles, increased from 518 in 1973 to 1,033 in 1974. The proportion of ducklings produced from natural cavities and nest boxes, 60 and 40%, respectively, remained essentially constant for the two seasons, although production in nest boxes was retarded by vandalism, and experimentation and production in natural cavities was increased by raccoon control in 1974.

The Ohio State University, Columbus.—Vegetation from two strip-mined areas in eastern Ohio was analyzed to measure its nutritive value for wildlife that might feed on it. Plant samples were collected seasonally from mined and adjacent nonmined (control) areas. Stripped lands provided food of low nutritional quality in winter, but overall nutritional quality was not greatly different from that of vegetation in control areas. Median levels of manganese commonly exceeded 500 ppm in vegetation from one strip-mined area, and some plants from strip-mined areas contained as much as 50 ppm of lead.

However, plants from control plots generally were higher in lead and mercury content than plants from strip-mined plots.

To complement the above project, a study was undertaken to ascertain concentrations of mercury, lead, and cadmium in wild mammals inhabiting strip-mined areas in eastern Ohio. Specimens were collected seasonally by trapping, sport hunting, and retrieving road kills, and their leg muscles, liver, kidneys, bones, and fur were analyzed. No significant trends were established to suggest that higher levels of the three metals were being concentrated in wildlife inhabiting the strip-mined areas. Generally, plants on the control areas had higher levels of the metals than plants on the stripped areas, suggesting that surface mining might be lowering the amounts of heavy metal available for ingestion by wildlife.

Oklahoma State University, Stillwater.—Aerial and ground surveys indicated that between 550 and 600 bald eagles winter in Oklahoma. Band return data and information about the nesting dates of southern bald eagles suggest that these eagles belong primarily to the northern race and that they probably nest in the western Great Lakes Region and south-central Canada. Canada geese, cottontail rabbits, and gizzard shad were the main prey items found in eagle pellets. Fifteen communal roosting sites, each occupied by 12-100 eagles, were studied and recommendations were made to protect these roosts.

Six hundred acres containing four clearings were fenced in the Ozark Mountains in 1967. The clearings were planted to native and cultivated forage plants to test their value as food for white-tailed deer and to compare their production and nutritional quality. Planted clearings were potentially beneficial to deer because large quantities of forage were produced. The nutritional quality of the cultivated forage was higher than that of native species eaten by deer, and the deer fed to a great degree on the cultivated species. Foraging in the clearings intensified when mast yields were low, indicating that clearings could have important survival value when native forage species were insufficient.

Oregon State University, Corvallis.—Pileated woodpeckers are dependent on a forest habitat for feeding and nesting. The alteration of this habitat through intensive timber management is detrimental to the species because of the reduction in dead wood, both standing and fallen. In a study in eastern Oregon, nests were excavated in large (58 cm diameter at breast height), tall (>12 m), ponderosa pine and larch snags. These nest trees were in forest sites containing the highest densities of stems and snags on the study area. Critical components in pileated woodpecker habitat are snags—particularly large snags—logs, large trees, diseased trees, and dense timber.



Collecting samples of vegetation on an area in Ohio strip-mined for coal. The vegetation was analyzed for its nutritive value to wildlife.
(Photo by R. D. Curnow)

The requisite attributes of size, density, and decadent trees are most common in mature, uncut forests, but these elements can be maintained at a satisfactory level for the big woodpeckers with moderate modifications of current forest management practices.

Distribution of nest sites and reproductive success were determined for prairie falcons breeding in Oregon during 1973-74. A total of 63 breeding attempts were monitored in a variety of habitats at elevations ranging from 200 to 8,300 feet. Pair bonds were formed as early as mid-March and, on the average, incubation began 16 April. The incubation period averaged 30 days while the nestling period lasted 41 days. The mean clutch size of 4.03 eggs resulted in 2.49 fledglings per breeding attempt. Application of a life equation and a structural model to estimates of mortality and observed productivity in Oregon indicated that the prairie falcon population in Oregon may be decreasing. Estimates of production were

about 20% below that necessary to maintain a stationary population.

Pennsylvania State University, University Park.—Ecological and behavioral studies of the black bear in Pennsylvania have emphasized the need for physiological studies and the demonstration of normal blood values. In a recent study, 66 blood samples from 44 black bears live-trapped in northeastern Pennsylvania provided the data for establishing normal values for 30 blood chemical and hematological characteristics. Significant changes in blood physiology that were related to some ecologic-physiologic coactions have occurred. For example, female bears had significantly lower calcium, serum glutamic oxalacetic transaminase (SGOT), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) than male bears. Since the blood of bears contains high concentrations of iron, these changes may relate to increased calcium and



Pileated woodpecker at nesting hole. Biologists of the Oregon Cooperative Wildlife Research Unit studied the nesting habitat of this woodpecker in relation to forest management practices. (Photo by B. Meanley)



Ecological and behavioral studies of the black bear have been conducted in Pennsylvania. The studies pointed up the need for establishing normal hematological and blood chemical values. (Photo by E. P. Haddon)

iron demands on females during pregnancy and lactation. Higher levels of SGOT in males than in females may be linked to the greater physical activity of males. This is indicated by movement data collected during the study. For both sexes, late summer and fall samples had significantly higher blood urea nitrogen (BUN), glucose, hematocrit, and mean corpuscular volume (MCV), but lower MCHC levels. High BUN and glucose levels suggest diets that are higher in protein and carbohydrates in summer and may be related to observed changes in seasonal foods. Increased hematocrit and MCV and lower MCHC values in conjunction with probably greater blood volume (a result of large weight gains) in the fall indicate possible increased activity of blood producing organs and a release of immature erythrocytes into the circulatory system. This work suggests the potential utility of blood studies to black bear management and provides a basis for future studies of disease, nutrition, physiology, mortality, and behavior.

South Dakota State University, Brookings.—In a study that compared drainage rate in channelized tributaries of

Wild Rice Creek with unchannelized sections of the creek in North and South Dakota, channelization was found to have an adverse effect on wildlife by reducing overbank flows and providing drainage outlets for potholes. After the project was approved but before construction began, approximately 3 times more wetland basins were drained on the channelized area than on the unchannelized portion of the study area, and more than 7 times as much acreage was drained on the channelized portion of the study area than on the unchannelized portion. During and after construction, these figures increased to 7 times for the number of wetlands drained and 10 times for acreage drained on channelized vs. unchannelized stream sections. Channelization increased wetland drainage or improved its feasibility, and the presence of the drainage outlet was a major influence on decisions by landowners to drain.

Most nest sites of the sharp-tailed grouse are in rolling grassland range and in pastures grazed in early spring or in summer, or on deferred rotation grazing. Vegetation around nests was consistently higher than the pasture



The Utah prairie dog, an endangered species, has experienced detrimental changes in its range because of over grazing by livestock. Reseeding with crested wheatgrass has benefited the species. (Photo by D. Crocker-Bedford)

average for the same range site. Vegetation used for nesting cover also provided good brood rearing cover. Both early spring grazing and deferred rotation grazing were found to be beneficial for nesting and brooding sharptail hens. Pasture management plans allowing 4-6 inches of good grassy vegetation in the spring would provide adequate cover for nesting.

Utah State University, Logan.—It is commonly thought that overgrazing by domestic livestock favors prairie dog populations. If true, grazing could be a management tool for the Utah prairie dog, which is an endangered species. However, a study of this species' diet, density, and distribution in relation to vegetation indicates that overgrazing is detrimental. Overgrazing in the past appeared to have changed the plant species composition on many rangelands from palatable, cool season vegetation to less palatable vegetation or warm season forage. In any case, little, if any, quality prairie dog forage is now available on many ranges during the prairie dog's reproductive period. Also, overgrazing apparently contributed to the formation of gullies, which destroyed swales that were important summer feeding grounds for the Utah prairie dog.

Since 1973, Unit personnel have studied one of the largest nesting populations of the white-faced ibis in North America. Prior to this, other Fish and Wildlife Service personnel documented a decline in the Utah ibis population which coincided with the development of thin eggshells and the use of high levels of DDE. An increase in the number of breeding pairs of ibises was recorded through 1974, and the incidence of thin-shelled eggs decreased at the same time. These biological responses correspond well with the cessation of DDT use in Utah.

Virginia Polytechnic Institute and State University, Blacksburg.—Pine voles were collected from two orchards, one a mature orchard maintained for com-



Neck-banded giant Canada goose. Geese were marked in this way to study the mortality and distribution of a declining flock wintering in southern Wisconsin. (Photo by S. R. Craven)

mercial apple production, the other an over-mature one that had been abandoned for 6 years. Stomach contents of 110 voles from the orchards were examined microscopically. In both orchards, the above-ground parts of grasses and forbs composed over 84% of the identifiable epidermal fragments in the stomachs. Significantly ($P < 0.01$) more forbs were consumed in the abandoned than in the producing orchard. The consumption of both grasses and forbs varied significantly ($P < 0.01$) among months. Forbs seemed to be preferred during spring and summer and grasses during fall and winter. Consumption of root material also varied significantly among months; total root consumption was greatest in both orchards during January and March. Voles from the producing orchard contained significantly more apple fragments than voles from the abandoned orchard.

Body fat contents of 244 voles from the orchards were ascertained by ether extraction. Voles from the abandoned orchard were significantly ($P > 0.05$) fatter than those from the maintained orchard. In November there was a change in the usual relationship of fat content between the two vole populations; fat content in both sexes was lower (the lowest values observed) in the abandoned orchard. It was postulated that a decline in the quality and quantity of food in the abandoned orchard resulted in low body fat levels and the cessation of reproduction. Between November and January body fat accumulated in the voles in the abandoned orchard. However, during late winter fat levels decreased in both vole populations. Body fat measurements, supplemented with data about reproductive activity, are useful in understanding the relationships between pine voles and their environment.



Pine voles damage the bark and roots of orchard trees. A knowledge of the habits and biology of the species may aid in devising methods for controlling this damage. (Fish and Wildlife Service photo)

University of Wisconsin, Madison.—Historically, giant Canada geese wintered near Hancock and Delevan, Wis. The Hancock flock disappeared about 1970, and the Delevan flock had declined from about 4,700 in 1942 to 1,500 in 1974. A study to determine factors responsible for this decline was begun in 1973. Aerial waterfowl surveys located a concentration of breeding geese in the Whiteshell Provincial Park in southeastern Manitoba, and recoveries of banded and color-marked birds indicate that this population winters near Delevan, Wis. These geese normally arrive in Wisconsin in early November, spend the winter on Rock Prairie Refuge and nearby Turtle Creek, and then depart for the breeding grounds in March. The incidence of a blood parasite, *Leucocytozoon*, is high in this flock, and productivity of the geese is relatively low. The high mortality rate among these birds is primarily due to hunting in Wisconsin and Manitoba. Although there is some interchange with other flocks of

geese wintering in Minnesota, Missouri, and Illinois, mortality associated with hunting has probably been the main cause of the decline.

In a study of white-tailed deer in central Wisconsin, transmitters were placed on 58 does and 2 bucks on two areas of high deer density during three winters, 1971-74. The average home range size for 19 deer, determined by at least 45 locations, was 194 acres. Home ranges overlapped and their shapes generally reflected the location of food and cover. The average major axis was 1.3 miles. Most deer were nonmigratory. Data from March through May showed activity peaks in early morning, mid-morning, and evening. On one area, swampland provided the major winter habitat and a combination of swamp, upland woods, and fields were inhabited during the rest of the year. Habitats used by the deer on the second area were more varied and interspersed than those of the first area.

PUBLICATIONS

Listed below are titles of articles published from 1 July 1974 to 30 June 1975 and a few papers published in 1973 that were not listed in the previous annual report. The articles were published in technical and scientific journals, magazines, proceedings, transactions, and other media.

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APPENDIX

Directory of Research Facilities and Personnel

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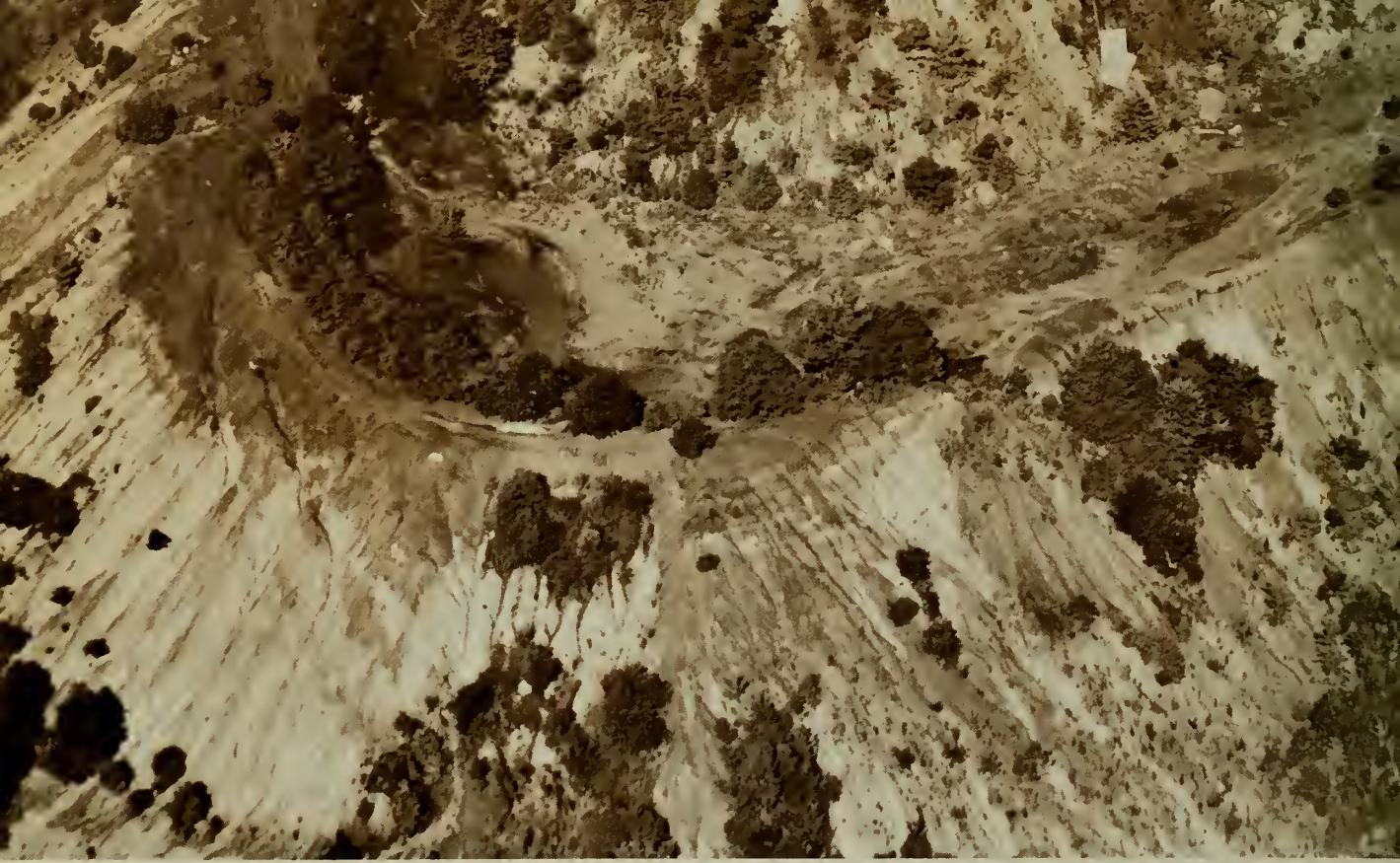
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A great white heron forages along the shore of a pool in the Everglades National Park. Originally thought to be a separate species, it is now considered a color variation of the great blue heron and is given subspecific rank. In the United States, it inhabits the Florida Keys and the extreme southern portion of peninsular Florida. It is a rare subspecies and is vulnerable to hurricanes and human encroachment on its habitat. (Photo by D. Q. Thompson)



Two surface mines abandoned in Virginia for more than 20 years. Poor handling of carbonaceous materials in the mine shown above has prevented the establishment of wildlife habitat on much of the bench and outslope. Vegetation on the mine shown below is recovering well, and wildlife habitat is relatively good. (Virginia Cooperative Wildlife Unit photos)

